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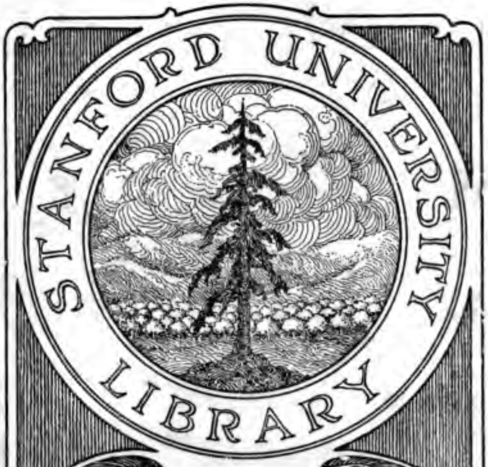

G. E. Stockle
U. S. M. H.

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Gal p 85

m 58 to 94

Zn p 154

p 185 $FeCO_3$

" 228 KNO_3

" 265 mica

" 327 coal,

" 430 limestones

[illegible] p 92 [illegible]

Fe p [illegible]

19 [illegible]

07 serpentine

430 limestone Kemp Geol.

MANUAL
OF
MINERALOGY AND LITHOLOGY,

CONTAINING

The Elements of the Science of Minerals and Rocks.

FOR THE USE OF

THE PRACTICAL MINERALOGIST AND GEOLOGIST, AND FOR INSTRUCTION IN SCHOOLS AND COLLEGES.

BY JAMES D. DANA.

THIRD EDITION.
RE-ARRANGED AND RE-WRITTEN.
FOURTEENTH THOUSAND.
ILLUSTRATED BY NUMEROUS WOOD-CUTS.

NEW YORK:
JOHN WILEY & SONS.
1886.

PREFACE.

THIS Manual in its present shape is new throughout. In the renovation it has undergone, new illustrations have been introduced, an improved arrangement of the species has been adopted, the table for the determination of minerals has been reconstructed, and the chapter on rocks has been expanded to a length and fullness that renders it a prominent part of the work. But while modified greatly in all its parts, it is still simple in its methods of presenting the facts in crystallography, and in all other explanations ; and special prominence is given, as in former editions, to the more common minerals, with only a brief mention of others. The old practical feature is retained of placing the ores under the prominent metal they contain, and of giving in connection some information as to mines and mining industry.

The student is referred to the Text-book of Mineralogy, prepared mainly by Mr. E. S. DANA, for a detailed exposition of the subject of crystallography after Naumann's and Miller's systems, and also of optical mineralogy and other physical branches of the science; to the Manual of Determinative Mineralogy and Blowpipe Analysis by Professor GEORGE J. BRUSH, for a thorough work on the use of the blowpipe, and complete tables for the determination of minerals; and to the author's Descriptive Mineralogy and its Appendixes for a comprehensive treatise on all known minerals.

JAMES D. DANA.

NEW HAVEN, Nov. 1, 1878.

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MINERALOGY.

MINERALS.

MINERALS are the materials of which the earth consists, and plants and animals the living beings over the surface of the mineral-made globe. A few rocks, like limestone and quartzyte, consist of a single mineral in more or less pure state; but the most of them are mixtures of two or more minerals. Through rocks of each kind various other minerals are often distributed, either in a scattered way, or in veins and cavities. Gems are the minerals of jewelry; and ores, those that are important for the metal they contain. Water is a mineral, but generally in an impure state from the presence of other minerals in solution. The atmosphere, and all gaseous materials set free in volcanic and other regions, are mineral in nature, although, because of their invisibility, seldom to be found among the specimens of mineral cabinets. Even fossils are mineral in composition. This is true of coal which has come from buried plant-beds, and amber from the buried resin of ancient trees, as well as of fossil shells and corals.

It is sometimes said that minerals belong to the *mineral kingdom*, as plants to the vegetable kingdom, and animals to the animal kingdom. Substituting the term *inorganic* for mineral, the statement is right; for, as there are the two kingdoms of life, so there is in Nature what may be called a kingdom, or grand division, including all species not made through the organizing principle of life. But this inorganic kingdom is not restricted to minerals; it embraces all species made by inorganic forces—those of the earth's crust or surface, and, also, whatever may form under the manipulations of the chemist. The laws of composition and structure, exemplified in the constitution of rocks, are those also of the laboratory. A species made by art, as we term it, is not a product of art, but a result solely of the fundamental laws of composition which are at the basis of all material existence; and the chemist only supplies the favorable conditions for the action of those laws. Mineral species, are then, but a very small part of those which make up the inorganic kingdom or division of Nature.

CHARACTERS OF MINERALS.

1. Minerals, unlike most rocks, have a definite chemical composition. This composition, as determined by chemical analysis, serves to define and distinguish the species, and indicates their profoundest relations. Owing to difference in composition, minerals exhibit great differences when heated, and when subjected to various chemical reagents, and these peculiarities are a means of determining the kind of mineral under examination in any case. The department of the science treating of the composition of minerals and their chemical reactions is termed CHEMICAL MINERALOGY.

2. Each mineral, with few exceptions, has its definite form, by which, when in good specimens, it may be known, and as truly so as a dog or cat. These forms are cubes, prisms, double pyramids, and the like. They are included under plane surfaces arranged in symmetrical order, according to mathematical law. These forms, in the mineral kingdom, are called *crystals.* Besides form there is also, as in living individuals, a distinctive internal structure for each species. The facts of this branch of the science come under the head of CRYSTALLOGRAPHIC MINERALOGY.

3. Minerals differ in *hardness*—from the diamond at one end of the scale to soapstone at the other. There is a still lower limit in liquids and gases; but of the hardness or cohesion in this part of the series the mineralogist has little occasion to take note.

Minerals differ in *specific gravity*, and this character, like hardness, is a most important means of distinguishing species.

Minerals differ in *color*, *transparency*, *lustre*, and other optical characters.

A few minerals have *taste* and *odor*, and when so these characters are noticed in descriptions.

The facts and principles relating to the above characters are embraced in the department of PHYSICAL MINERALOGY.

In addition to the above-mentioned branches of the science of minerals there is also (4) that of DESCRIPTIVE MINERALOGY, under which are included descriptions of the mineral species; and (5) that of DETERMINATIVE MINERALOGY, which gives a systematic review of the methods for determining or distinguishing minerals.

These different branches of the subject are here taken up in the following order: I. Crystallographic Mineralogy; II. Physical Mineralogy; III. Chemical Mineralogy; IV. Descriptive Mineralogy; V. Determinative Mineralogy. On account of the brief manner in which the subjects are treated in this volume, the heads used for the several parts are, (1) *The Crystallization of Minerals;* (2) *Physical Properties of Minerals;* (3) *Chemical Properties of Minerals;* (4) *Descriptions of Species;* (5) *Determination of Minerals.*

1. CRYSTALLIZATION OF MINERALS: CRYSTALLOGRAPHY.

1. General Remarks on Crystallization.

The attraction which produces crystals is one of the fundamental properties of matter. It is identical with the cohesion of ordinary solidification; for there are few cases outside of the kingdoms of life in which solidification takes place without some degree of crystallization. Cohesive attraction is, in fact, the organizing or structure-making principle in inorganic nature, it producing specific forms for each species of matter, as life does for each living species. A bar of cast-iron is rough and hackly in surface, because of the angular *crystalline* grains which the iron assumed as solidification took place. A fragment of marble glistens in the sun, owing to the reflection of light from innumerable crystalline surfaces, every grain in the mass having its crystalline structure. When the cold of winter settles over the earth in the higher temperate and colder latitudes it is the signal for crystallization over all out-door nature; the air is filled with crystal flakes when it snows; the streams become coated with an aggregation of crystals called ice; and windows are covered with frost because crystal has been added to crystal

CRYSTALS OF SNOW.

in long feathered lines over the glass—Jack Frost's work being the making of crystals. Water cannot solidify without crystallizing, and neither can iron nor lead, nor any mineral material, with perhaps half a dozen exceptions. Crystallization produces masses made of crystalline grains when it cannot make distinct crystals. Granite mountains are mountains of crystals, each particle being crystalline in nature and structure. The lava current, as it cools, becomes a mass of crystalline grains. In fact the earth may be said to have crystal foundations; and if there is not the beauty of external form, there is everywhere the interior, profounder beauty of universal law—the same law of symmetry which, when external circumstances permit, leads to the perfect crystal with regular facets and angles.

Crystals are alone in making known the fact that this law of symmetry is one of the laws of cohesive attraction, and that under it this attraction not only brings the particles of matter into forms of mathematical symmetry, but often develops scores of brilliant facets over their surface with mathematical exactness of angle, and the simplest of numerical relations in their positions. Crystals teach also the more wonderful fact that the same species of matter may receive, under the action of this attraction, through some yet incomprehensible changes in its condition, a great diversity of forms—from the solid of half a dozen planes to one of scores. The following figures represent a few of the forms in a common species, pyrite, a compound of iron and sulphur.

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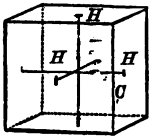

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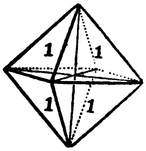

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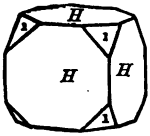

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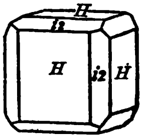

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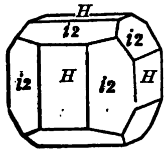

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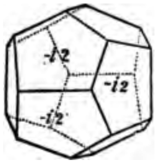

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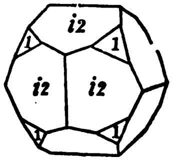

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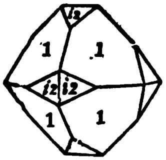

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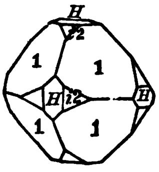

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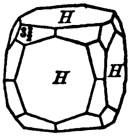

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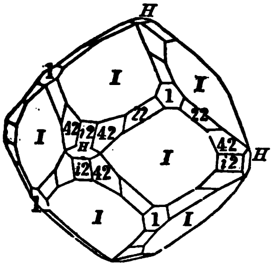

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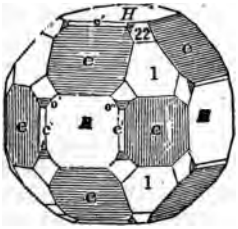

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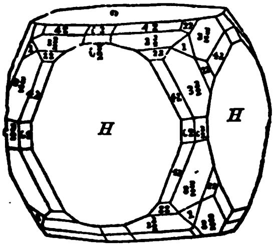

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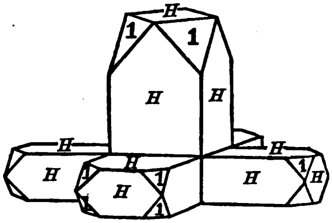


Many more figures might be given for this one species, pyrite. The various forms or planes in any such case have, it is true, mutually dependent relations—a fact often expressed by saying that they have a common *fundamental form*. But it is none the less a remarkable fact, giving profound interest to the subject, that the attraction, while having this degree of unity in any species, still, under each, admits of the multitudinous variations needed to produce so diverse results.

At the time of crystallization the material is usually in a state of fusion, or of gas or vapor, or of solution. In the case of iron the crystallization takes place from a state of fusion, and while the result is ordinarily only a mass of crystalline grains, distinct crystals are sometimes formed in any cavities. If in the cooling of a crucible of melted lead, bismuth, or sulphur, the crust be broken soon after it forms, and the liquid part within be turned out, crystals will be found covering the interior. Here, also, is crystallization from a state of fusion. When frost or snow-flakes form it exemplifies crystallization from a state of vapor. If a saturated solution of alum, made with hot water, be left to cool, crystals of alum after awhile will appear, and will become of large size if there is enough of the solution. A solution of common salt, or of sugar, affords crystals in the same way. Again, whenever a mineral is produced through the change or decomposition of another, and at the same time assumes the solid state, it takes at once a crystalline structure, if it does not also develop crystals.

Further, the crystalline texture of a solid mass may often be changed without fusion: *e. g.*, in tempering steel the bar is changed from coarse-grained steel to fine-grained by heating and then cooling it suddenly in cold water, and *vice versa*, and this is a change in every grain throughout the bar.

Thus the various processes of solidification are processes of crystallization, and the most universal of all facts about minerals is that they are crystalline in texture. A few exceptions have been alluded to, and one example of these is the mineral opal, in which even the microscope detects no evidence of a crystalline condition, except sometimes in minute portions supposed not to be opal. But if we exclude coals and resins this mineral stands almost alone. Such facts, therefore, do not affect the conclusion that a knowledge of crystallography is of the highest importance to the mineralogist. It is important because—

1. A study of the crystalline forms and structure of minerals is a convenient means of distinguishing species—the crystals of a species being essentially constant in structure and in angles.
2. The most important optical characters depend on the crystallization, and have to be learned from crystals.
3. The profoundest chemical relations of minerals are often exhibited in the relations of their crystalline forms.
4. Crystallization opens to us nature at her foundation work and illustrates its mathematical character.

2. Descriptions of Crystals.

In describing crystals there are two subjects for consideration: First, Form; and secondly, Structure.

A. Form.—Under *form* come up for description, not only the general forms of crystals, but also—

(1.) The systems of crystallization, that is, the relations of *all* crystalline forms, and their classification.

(2.) The mutual relations of the planes of a crystal as ascertained through their positions and the angles between them.

(3.) The distortions of crystals. The perfection of symmetry exhibited in the figures of crystals, in which all similar planes are represented as having the same size and form, is seldom found in nature, and the true form is often greatly disguised by this means. The facts on this point, and the methods of avoiding wrong conclusions need to be understood, and these are given beyond. With all such imperfections *the angles of crystals remain essentially constant.* There are irregularities also from other sources.

(4.) Twin or compound crystals. With some species *twins* are more common than regular crystals.

(5.) Crystalline aggregates, or combinations of imperfect crystals, or of crystalline grains.

Explanations of Terms.

The following are explanations of a few terms used in connection with this subject:

1. *Octahedron.*—A solid bounded by *eight* equal triangles. They are equal equilateral triangles in the *regular* octahedron (Fig. 2, p. 17); equal isosceles triangles in the *square* octahedron (Fig. 17, p. 32); equal inequilateral triangles in the *rhombic* octahedron (Fig. 8, p. 37).

2. *Double six-sided pyramids. Double eight-sided pyramids. Double twelve-sided pyramids.*—Solids made of two equal equilateral six-sided, or eight-sided, or twelve-sided, pyramids placed base to base (Fig. 20, p. 32, and 6, 10, pp. 46, 47).

3. *Right prisms. Oblique prisms.*—Right prisms are those that are erect, all their sides being at right angles to the base. When inclined, they are called *oblique* prisms.

4. *Interfacial angle.*—Angle of inclination between two faces or planes.

5. *Similar planes. Similar angles.*—The lateral faces of a square prism (Fig. 2, p. 14) are equal and have like relations to the axes, and hence they are said to be *similar.* Solid angles are *similar* when the plane angles are equal each for each, and the enclosing planes are severally similar in their relations to the axes.

6. *Truncated. Bevelled.*—An edge of a crystal is said to be *truncated* when it is replaced by a plane *equally* inclined to the enclosing planes, as in Fig. 13, p. 19; and it is *bevelled* when replaced by two planes

equally inclined severally to the adjoining faces. Only edges that are formed by the meeting of two *similar* planes can be truncated or bevelled. The angle between the truncating plane and the plane adjoining it on either side always equals 90° *plus* half the interfacial angle over the truncated edge. When a rectangular edge, or one of 90°, is truncated, this angle is accordingly 135° (=90°+45°); when an edge of 70°, it is 125° (=90°+35°); when an edge of 140°, it is 160° (=90°+70°).

7. *Zone.*—A zone of planes includes a series of planes having the edges between them, that is, their mutual intersections, all parallel. Thus in Fig. 14, on page 6, *O* at top of figure, *i*2, $i\frac{3}{2}$, *O* in front, and two planes below, and others on the back of the crystal are in one zone, a vertical zone. Again, in the same figure, *O* at top, 42, $3\frac{3}{2}$, 22, 42, *i*2, 42, 22, $3\frac{3}{2}$, and the continuation of this series below and over the back of the crystal lie in another vertical zone. And so in other cases, in other directions. All planes in the same zone may be viewed as on the circumference of the same circle. The planes of crystals are generally all comprised in a few zones, and the study of the mathematics of crystals is largely the study of zones of planes.

Axes.—Imaginary lines in crystals intersecting one another at their centres. Axes are assumed in order to describe the positions of the planes of crystals. In each system of crystallization there is one *vertical* axis, and in all but hexagonal forms there are *two lateral* axes.

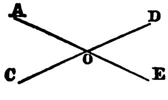
Diametral sections.—The sections of crystals in which lie any two of the axes. In forms having two lateral axes, there are two vertical diametral sections and one basal.

Diametral prisms.—Prisms whose sides are parallel to the diametral sections.

Measurement of Angles.

The angles of crystals are measured by means of instruments called *goniometers*. These instruments are of two kinds, one the *common goniometer*, the other, the *reflecting goniometer*.

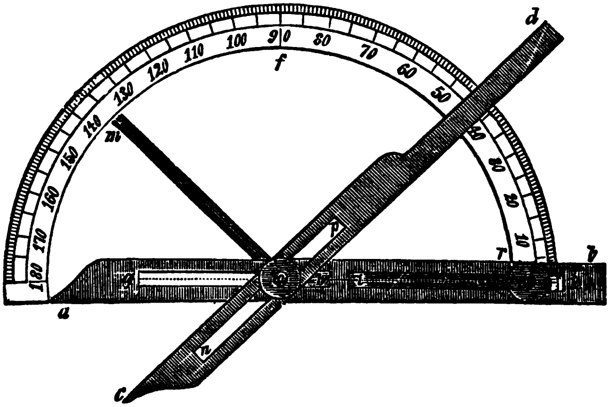
The *common goniometer* depends for its use on the very simple principle that when two straight lines cross one another, as A E, C D, in the annexed figure, the parts will diverge equally on opposite sides of the point of intersection (O); that is in mathematical language, the angle A O D is equal to the angle C O E, and A O C is equal to D O E.



A common form of the instrument is represented in the figure on page 10.

The two arms *a b*, *c d*, move on a pivot at *o*, and their divergence, or the angle they make with one another, is read off on the graduated arc attached. In using it, press up between the edges *a o* and *c o*, the edge of the crystal whose angle is to be measured, and continue thus opening the arms until these edges lie evenly against the faces that include the required angle. To insure accuracy in this respect, hold the instrument and crystal between the eye and the light, and observe that no light passes between the arm and the applied faces of the crystal. The arms may then be secured in position by tightening the screw at *o*; the angle will then be measured by the distance on the arc from *k* to the *left* or *outer* edge of the arm *c d*, this edge being in the line of *o*, the centre of motion. As the instrument stands in the figure, it reads 45°. The arms have slits at *g h*, *n p*, by which the parts *a o*, *c o*, may be shortened so as to make them more convenient for measuring small crystals.

In the best form of the common goniometer the arc is a complete



circle, of larger diameter than in the above figure, and the arms are separate from it. After making the measurement, the arms are laid upon the circle, with the pivot at the centre of motion inserted in a socket at the centre of the circle. The inner edge of one of the arms is then brought to zero on the circle, and the angle is read off as before.

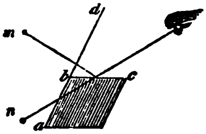
With a little ingenuity the student may construct a goniometer for himself that will answer a good purpose. A semicircle may be described on mica or a glazed card, and graduated. The arms might also be made of stiff card for temporary use; but mica, bone, or metal is better. The arms should have the edges straight and accurately parallel, and be pivoted together. The instrument may be used like that last described, and will give approximate results, sufficiently near for distinguishing most minerals. The ivory rule accompanying boxes of mathematical instruments, having upon it a scale of sines for measuring angles, will answer an excellent purpose, and is as convenient as the arc.

In making such measurements it is important to have in mind the fact that—

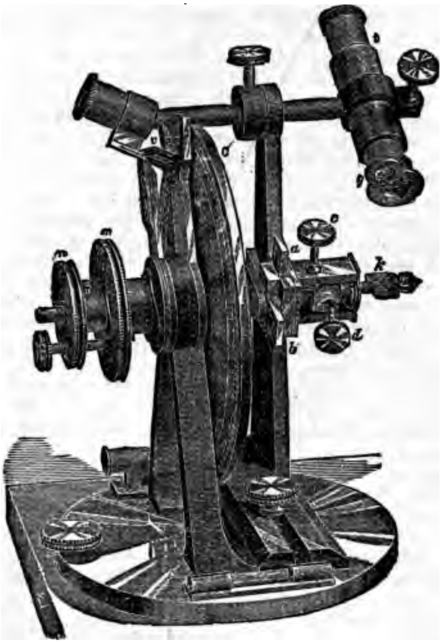
1. The sum of the angles about a centre is 360°.
2. In a rhomb, as in a square, the sum of the plane angles is 360°.

In any polygon, the *supplements of the angles equals* 360°, *whatever the number of sides.* For example: in a square, the four angles are each 90°, and hence the supplements are 90°, and 4 × 90=360; again, in a regular hexagon the six angles are each 120, the supplements are 60°, and 6 × 60=360. So for all polygons, whether regular or irregular. In measuring the angles it is therefore convenient to take down the supplements of the angles. This principle is conveniently applied in the measurement of all the angles of a zone of planes around the crystal; for the sum of all the supplements should be, as above, 360° and if this result is not obtained there is error somewhere.

The *reflecting goniometer* affords a more accurate method of measuring crystals that have lustre, and may be used with those of minute size. The principle on which this instrument is constructed will be understood from the annexed figure, representing a crystal, whose angle *a b c* is required. The eye, looking at the face of the crystal *b c*, observes a reflected image of *m*, in the direction P *n*. On revolving the crystal till *a b* has the position of *b c*, the same image will be seen again in the same direction P *n*. As the crystal is turned, in this revolution, till *a b d* has the present position of *b c*, the angle *d b c* measures the number of degrees through which it is revolved. But *d b c* subtracted from 180° equals the angle of the crystal *a b c*. The crystal is therefore passed, in its revolution, through a number of degrees equal to the supplement of the required angle.



This angle, in the reflecting goniometer of Wollaston, is measured by attaching the crystal to a graduated circle which revolves with it, one form of which is here represented.



C is the graduated circle. The wheel, *m*, is attached to the main axis, and moves the graduated circle together with the adjusted crystal.

The wheel, *n*, is connected with an axis which passes through the main axis (which is hollow for the purpose), and moves merely the parts to which the crystal is attached, in order to assist in its adjustment. The contrivances for the adjustment of the crystal are at *a*, *b*, *c*, *d*, *k*. The screws, *c*, *d*, are for the adjustment of the crystal, and the slides, *a*, *b*, serve to centre it.

To use the instrument, it may be put on a stand or small table, with its base accurately horizontal, and the table placed in front of a window, six to twelve feet off, with the plane of its circle at right angles to the window. A dark line must then be drawn below the window, near the floor, parallel to the bars of the window, and about as far from the eye as from the window-bar.

The crystal is attached to the movable plate *k* by means of wax, and so arranged that the edge of intersection of the two planes forming the required angle, shall be in a line with the axis of the instrument. This is done by varying its situation on the plate, or by means of the adjacent screws and slides.

When apparently adjusted, the eye must be brought close to the crystal, nearly in contact with it, and on looking into a face, part of the window will be seen reflected, one bar of which must be selected for the trial. If the crystal is correctly adjusted, the selected bar will appear horizontal, and on turning the wheel *n*, till this bar, as *reflected*, is observed to approach the dark line below seen in a *direct* view, it will be found to be parallel to this dark line, and ultimately to coincide with it. The eye for both observations should be held in precisely the same position. If there is not a perfect coincidence, the adjustment must be altered until this coincidence is obtained. Continue then the revolution of the wheel *n*, till the same bar is seen by reflection in the next face, and if here there is also a coincidence of the reflected bar with the dark line seen direct, the adjustment is complete; if not, alterations must be made, and the first face again tried. In an instrument like the one figured, the circle is usually graduated to twenty or thirty minutes, and, by means of the vernier, minutes and half minutes are measured. After adjustment, 180° on the arc must be brought opposite 0, on the vernier, *v*. The coincidence of the bar and dark line is then to be obtained, by turning the wheel *n*. When obtained, the wheel *m* should be turned until the same coincidence is observed, by means of the next face of the crystal. If a line on the graduated circle now corresponds with 0 on the vernier, the angle is immediately determined by the number of degrees opposite this line. If no line corresponds with 0, we must observe which line on the vernier coincides with one on the circle. If it is the 18th on the vernier, and the line on the circle next below 0 on the vernier marks 125°, the required angle is 125° 18′; if this latter line marks 125° 20′, the required angle is 125° 38′.

In the better instruments other improved methods of arrangement are employed; and in the best, often called Mitscherlich's goniometer, because first devised by him, there are two telescopes, one for passing a ray of light upon the adjusted crystal, having crossed hair lines in its focus, and the other for viewing it, also with a hair cross. With such an arrangement, the window-bar and dark line are unnecessary, the hair crosses serving to fix the position of the crystal, and the telescope that of the eye. If the crystal is perfect in its planes, and the adjustment exact, the measurement, with the best instruments, will give the angle within 10″.

Other goniometers have only the second of the two telescopes just alluded to, as is the case in the figure on page 11. This telescope gives a fixed position to the eye; and through it is seen a reflection of some distant object, which may be even a chimney-top. For the measurement the object, seen reflected in the two planes successively, is brought each time into conjunction with the hair cross. Exact adjustment is absolutely essential, and with an instrument having the two telescopes, the first step in a measurement cannot be taken without it.

Only small, well-polished crystals can be accurately measured by the reflecting goniometer. If, when using the instrument without telescopes, the faces do not reflect distinctly a bar of the window, the flame of a candle or of a gas-burner, placed at some distance from the crystal, may be used by observing the flash from it with the faces in succession as the circle is revolved. A ray of sun-light from a mirror, received on the crystal through a small hole, may be employed in a similar way. But the results of such measurements will be only approximations. With two telescopes and artificial light, and with a cross slit to let the light pass in place of the cross hairs of the first of the above-mentioned telescopes, this light cross will be reflected from the face of a crystal even when it is not perfect in polish, and quite good results may be obtained.

B. STRUCTURE.—Structure includes cleavage, a characteristic of crystals intimately connected with their forms and nature. It is the property, which many crystals have, of admitting of subdivision indefinitely in certain directions, and affording usually even, and frequently polished, surfaces. The direction is always parallel with the planes of the axes, or with others diagonal to these.

The ease with which cleavage can be obtained varies greatly in different minerals, and in different directions in the same mineral. In a few species, like mica, it readily yields laminæ thinner than paper, and in this case the cleavage is said to be *eminent.* Others, of *perfect* cleavage, cleave easily, but afford thicker plates, and from this stage there are all grades to that in which cleavage is barely discernible or *difficult.* The cleavage surfaces vary in lustre from the most brilliant to those that are nearly dull. When cleavage in a mineral is alike in two or more directions, that is, is attainable in these directions with equal facility and affords surfaces of like lustre and character or marking, this is proof that the planes in those directions are similar, or have similar relations to like axes. For example, equal cleavage in *three* directions, at *right angles* to one another, shows that the planes of cleavage correspond to the faces of the cube; so equal cleavage in *two* directions, in a prismatic mineral, shows that the planes in the two directions are those of a square prism, or else of a rhombic prism; and if they are at right angles to one another that they are those of the former. This subject is further illustrated beyond.

In the following pages (1) the Systems of Crystallization and the Forms and Structure of Crystals are first considered; next, (2) Compound, or Twin Crystals; and then (3) Crystalline Aggregates.

1. SYSTEMS OF CRYSTALLIZATION: FORMS AND STRUCTURE OF CRYSTALS.

The forms of crystals are exceedingly various, while the ***systems*** of crystallization, based on their mathematical distinctions, are only *six* in number. Some of the simplest of the forms under these six systems are the prisms represented in the following figures; and by a study of these forms the distinctions of the six systems will become apparent. These prisms are all four-sided, excepting the last, which is six-sided. In them the planes of the top and bottom, and any planes that might be made parallel to these, are called the *basal* planes, and the sides the *lateral* planes. An imaginary line joining the centres of the bases (*c* in figures 1 to 8) is called the ***vertical axis***, and the

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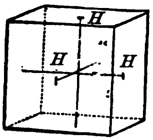

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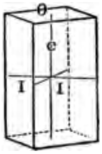

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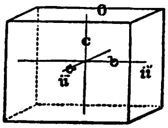

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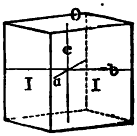

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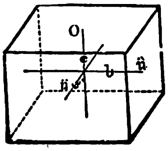

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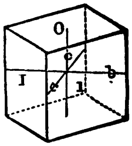

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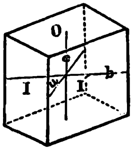

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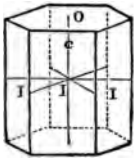

diagonals *a* and *b*, drawn in a plane parallel to the base, are the *lateral axes*.

Fig. 1 represents a cube. It has all its planes square (like fig. 9), and all its plane and solid angles, right angles, and the three axes consequently *cross at right angles* (or, in other words, make *rectangular intersections*) and are *equal*. It is an example under the first of the systems of crystallization, which system, in allusion to the equality of the axes, is called the *Isometric system*, from the Greek for *equal* and *measure*.

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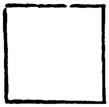

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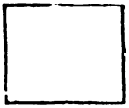

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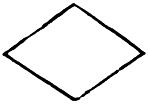

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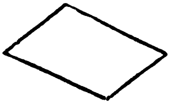

Fig. 2 represents an erect or right square prism having all its plane angles and solid angles rectangular. The base is square or a tetragon, and consequently the *lateral axes are equal and rectangular in their intersections*; but, unlike a cube, *the vertical axis is unequal to the lateral.* There are hence, in the square prism, axes of two kinds making rectangular intersections. The system is hence called, in allusion to the two kinds of axes, the *Dimetric* system, or, in allusion to the tetragonal base, the *Tetragonal system.*

Fig. 3 represents an erect or right rectangular prism, in which, also, the plane angles and solid angles are rectangular. The base is a rectangle (fig. 10), and consequently the *lateral axes*, connecting the centres of the opposite lateral faces, are *unequal* and rectangular in their intersections; and, at the same time, *each is unequal to the vertical.* There are hence three unlike axes making rectangular intersections; and in allusion to the three unlike axes, the system is called the *Trimetric* system. It is also named, in allusion to its including erect prisms having a rhombic base, the *Orthorhombic system*, *orthos*, in Greek, signifying *straight* or *erect.*

This rhombic prism is represented in fig. 4. It has a rhombic base, like fig. 11; the lateral axes connect the centres of the opposite lateral edges; and hence they cross at right angles and are unequal, as in the rectangular prism. This right rhombic prism is therefore one in system with the right rectangular prism.

Fig. 5 represents another rectangular prism, and fig. 6

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A *mineral* is any substance in nature not organized by vitality and having a homogeneous composition. Very limited exceptions to the universality of this definition obtain, e. g., some kinds of mineral coal. Some minerals, more or less impure, e. g., calcite, form mountain masses; usually, however, *rocks* are mineral aggregates. Axes (p. 9) connect vertices of opposite angles, middle points of edges, or centres of opposite faces.

Crystals are solids formed by crystalline force and bounded by plane faces which, when the crystal is perfect, are symmetrically arranged. In the *same primary*, or fundamental form, the angles are always constant; some of the faces may be greatly enlarged at the expense of others, quite changing the appearance of the crystal.

Primary forms (or fundamental forms) are those *we* can derive by cleavage, or, in the case of secondaries, by studying the modifying planes. To these primaries there are a great many secondaries which *nature* produces by modifying their respective primaries. There are 13 primary forms of crystals, which on account of the relations obtaining among their axes may be arranged in six systems.

ORTHOMETRIC SYSTEMS.

ISOMETRIC=MONOMETRIC=TESSERAL SYSTEM.

Cube	Fig. 1, p. 17
Regular octahedron	Fig. 2, p. 17
Rhombic dodecahedron	Fig. 3, p. 17

DIMETRICTE=TETRAGONAL SYSTEM.

Right square prism	Fig. 10, p. 31
Square octahedron	Fig. 16, p. 32

TRIMETRIC=ORTHORHOMBIC SYSTEM.

Right rhombic prism	Fig. 12, p. 38
Right rectangular prism	Fig. 11, p. 38
Rhombic octahedron	Fig. 8, p. 37

CLINOMETRIC SYSTEMS.

MONOCLINIC SYSTEM.

Oblique rectangular= Right rhomboidal prism	Fig. 7, p. 41
Oblique rhombic prism	Fig. 8, p. 41

TRICLINIC SYSTEM.

Oblique rhomboidal prism	Fig. 7, p. 14

HEXAGONAL=RHOMBOHEDRAL SYSTEM.

Hexagonal prism	Fig. 4, p. 46
Rhombohedron: acute	Fig. 6, p. 49
Rhombohedron: obtuse	Fig. 18, p. 50

In the *obtuse* rhombohedron the lateral solid angles are formed of *two acute* plane angles and one obtuse plane angle: in the *acute* rhombohedron the reverse is the case.

Some minerals never occur in crystals; such are said to be amorphous. Mineral coal, opal, turquoise, limonite and wad are examples.

species and crystalline forms that are very close in their relations. There are forms under each of the systems that differ but little in angles from some of other systems: for example, square prisms that vary but slightly from the cubic form; triclinic that are almost identical with monoclinic forms; hexagonal that are nearly cubic. Consequently it is found that the same natural group of minerals may include both trimetric and monoclinic species, as is true of the Hornblende group; or monoclinic and triclinic, as is the fact with the Feldspar group, and so on. It is hence a point to be remembered, when the affinities of species are under consideration, that difference in crystallographic system is far from certain evidence that any species are fundamentally or widely unlike.

I. THE ISOMETRIC SYSTEM.

1. **Descriptions of Forms.** The following are figures of some of the forms of crystals under the isometric system:

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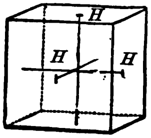

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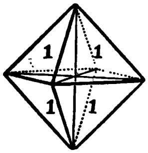

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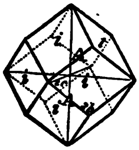

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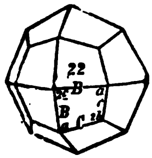

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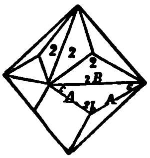

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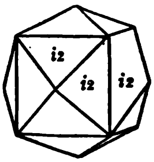

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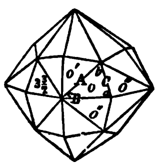

The first is the *cube* or *hexahedron*, already described. Besides the three cubic axes, there are equal diagonals in two other directions; one set connecting the apices of the diagonally opposite solid angles, *four* in number (because the number of such angles is eight), and called the *octahedral axes*; and another set connecting the centres of the diagonally opposite edges, *six* in number (because the number of edges is twelve), and called the *dodecahedral axes*.

Fig. 2 represents the *octahedron*, a solid contained under eight equal triangular faces (whence the name from the Greek *eight* and *face*), and having the three axes like those in the cube. Its plane angles are 60°; its interfacial angles, that is the inclination of planes 1 and 1 over an intervening edge (usually written $1 \wedge 1$) = 109° 28′; and 1 on 1 over a solid angle, 70° 32′.

Fig. 3 is the dodecahedron, a solid contained under *twelve* equal rhombic faces (whence the name from the Greek for *twelve* and *face*). The position of the cubic axes is shown in the figure. It has fourteen solid angles; six formed by the meeting of four planes, and eight formed by the meeting of three. The interfacial angles (or *i* on an adjoining *i*) are 120°; *i* on *i* over a four-faced solid angle = 90°.

Fig. 4 is a *trapezohedron*, a solid contained under 24 equal trapezoidal faces. There are several different trapezohedrons among isometric crystalline forms. The one here figured, which is the common one, has the angle over the edge *B*, 131° 49′, and that over the edge *C*, 146° 27′. A trapezohedron is also called a *tetragonal trisoctahedron*, the faces being tetragonal or four-sided, and the number of faces being 3 times 8 (*tris*, *octo*, in Greek).

Fig. 5 is another trisoctahedron, one having trigonal or three-sided faces, and hence called a *trigonal trisoctahedron*. Comparing it with the octahedron, fig. 2, it will be seen that three of its planes correspond to one of the octahedron. The same is true also of the trapezohedron.

Fig. 6 is a *tetrahexahedron*, that is a 4 × 6-faced solid, the faces being 24 in number, and four corresponding to each face of the cube or hexahedron (fig. 1).

Fig. 7 is a hexoctahedron, that is a 6 × 8-faced solid, a pyramid of six planes corresponding to each face in the octahedron, as is apparent on comparison. There are different kinds of hexoctahedrons known among crystallized isometric species, as well as of the two preceding forms. In each case the difference is not in number or general arrangement of planes, but in the angles between the planes, as explained beyond.

But these simple forms very commonly occur in combination with one another; a cube with the planes of an octahedron and the reverse, or with the planes of any or all of the other kinds above figured, and many others besides. Moreover, all stages between the different forms are often represented among the crystals of a species. Thus between the cube and octahedron, occur the forms shown in figs. 8 to 11. Fig. 12 is a cube; fig. 8 represents the cube with a plane on each angle, equally inclined to each cubic face; 9, the same, with the planes on the angles more enlarged and the cubic faces reduced in size; and then 10, the octahedron, with the cubic faces quite small; and fig. 11, the octahedron, the cubic faces having disappeared altogether. This transformation is easily performed by the student with cubes cut out of chalk, clay, or a potato. It shows the fact that the cubic axes (fig. 12) connect the apices of the solid angles in the octahedron.

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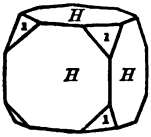

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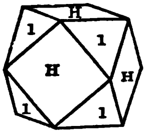

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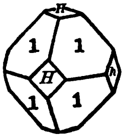

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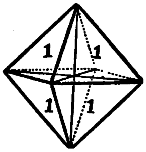

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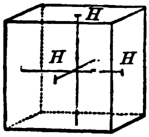

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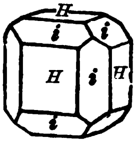

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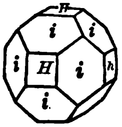

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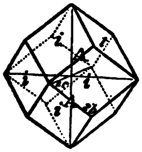

Again, between a cube and a dodecahedron there occur forms like figs. 13 and 14; fig. 12 being a cube, fig. 13 the same, with planes *truncating* the edges, each plane being equally inclined to the adjacent cubic faces, and fig. 14 another, with these planes on the edges large and the cubic faces small; and then, when the cubic faces disappear by farther enlargement of the planes on the edges, the form is a dodecahedron, fig. 15. The student should prove this transformation by trial with chalk or some other material, and so for other cases mentioned beyond. The surface of such models in chalk may be made hard by a coat of mucilage or varnish.

Again, between a cube and a trapezohedron there are the forms 17 and 18; 16 being the cube, 17, cube with three planes placed symmetrically on each angle; 18, the same with the cubic faces greatly reduced (but also with small octahedral faces), and 19, the trapezohedron, the cubic faces having disappeared.

Again, fig. 20 represents a cube with three planes on each angle, which, if enlarged to the obliteration of the faces of the cube, become the trigonal trisoctahedron, fig. 21. So again, fig. 22 represents a cube with six faces on each angle, which, if enlarged to the same extent as in the last, would become the hexoctahedron, fig. 23.

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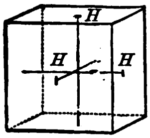

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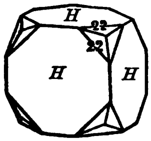

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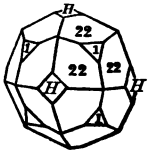

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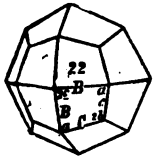

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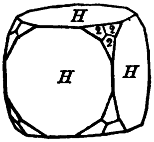

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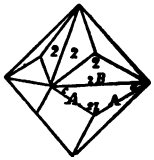

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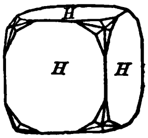

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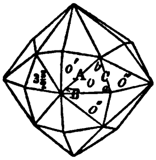

Again, fig. 25 is a form between the octahedron (fig. 24) and dodecahedron (fig. 26); and figs. 27 and 28 are forms between the dodecahedron, fig. 26, and trapezohedron, fig. 29.

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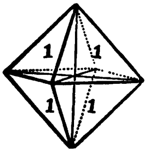

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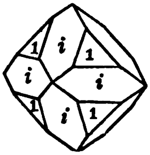

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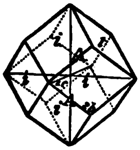

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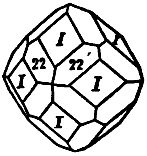

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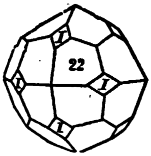

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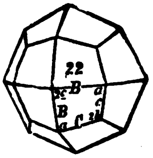
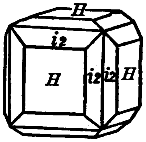


Again, fig. 30 is a form between a cube (fig. 16) and a tetrahexahedron, fig. 31; fig. 32, a form between an octahedron, fig. 24, and a tetrahexahedron, fig. 31; fig. 33, a form between an octahedron and a trigonal trisoctahedron, fig. 34; fig. 35, a form between a dodecahedron (planes *i*) and a tetrahexahedron; fig. 36, a form between the dodecahedron and a hexoctahedron, fig. 37.

30.



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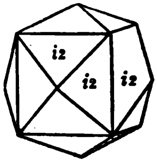

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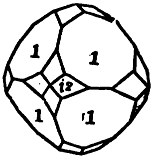

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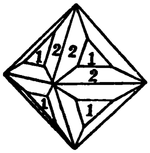

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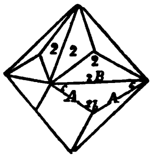

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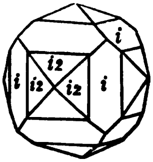

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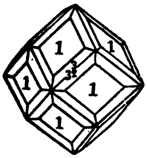

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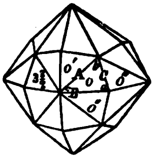

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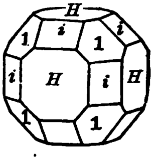


Fig. 38 represents a cube with planes of both the octahedron and dodecahedron.

2. Positions of planes with reference to the axes. Lettering of figures.—The numbers by which the planes in the above figures, and others of the work, are lettered, indicate the positions of the planes with reference to the axes, and exhibit the mathematical symmetry and ratios in crystallization. In the figure of the cube (fig. 1) the three axes are represented; the lateral semi-axis which meets the front planes in the figure is lettered *a*; that meeting the side plane to the right *b*, and the vertical axis *c*, and the other halves of the same axes respectively -*a*, -*b*, -*c*. By a study of the positions of the planes of the cube and other forms with reference to these axes, the following facts will become apparent.

In the cube (fig. 1) the front plane touches the extremity of axis a, but is parallel to axes b and c. When one line or plane is parallel to another they do not meet except at an infinite distance, and hence the sign for infinity is used to express parallelism. Employing i, the initial of infinity, as this sign, and writing c, b, a, for the semi-axes so lettered, then the position of this plane of the cube is indicated by the expression $ic : ib : 1a$. The top and side-planes of the cube meet one axis and are parallel to the other two, and the same expression answers for each, if only the letters a, b, c, be changed to correspond with their positions. The opposite planes have the same expressions, except that the c, b, a will refer to the opposite halves of the axes and be $-c$, $-b$, $-a$.

In the dodecahedron, fig. 15, the right of the two vertical front planes i. meets two axes, the axes a and b, at their extremities, and is parallel to the axis c. Hence the position of this plane is expressed by $ic : 1b : 1a$. So, all the planes meet two axes similarly and are parallel to the third. The expression answers as well for the planes i in figs. 13, 14, as for that of the dodecahedron, for the planes have all the same relation to the axes.

In the octahedron, fig. 11, the face 1, situated to the right above, like all the rest, meets the axes a, b, c, at their extremities; so that the expression $1c : 1b : 1a$ answers for all.

Again, in fig. 17 (p. 20) there are three planes, 2-2, placed symmetrically on each angle of a cube, and, as has been illustrated, these are the planes of the trapezohedron, fig. 19. The upper one of the planes 2-2 in these figures, when extended to meet the axes (as in fig. 19), intersects the vertical c at its extremity, and the others, a and b, at twice their lengths from the centre. Hence the expression for the plane is $1c : 2b : 2a$. So, as will be found, the left hand plane 2-2 on fig. 17, will have the expression $2c : 1b : 2a$; and the right hand one, $2c : 2b : 1a$. Further, the same ratio, by a change of the letters for the semi-axes, will answer for all the planes of the trapezohedron.

In fig. 20 there are other three planes, 2, on each of the angles of a cube, and these are the planes of the trisoctahedron in fig. 21. The lower one of the three on the upper front solid angle, would meet if extended, the extremities of the axes a and b, while it would meet the vertical axis at *twice* its length from the centre. The expression $2c : 1b : 1a$ indicates, therefore, the position of the plane. So also, $1c : 1b : 2a$ and $1c : 2b : 1a$ represent the positions of the other two planes adjoining; and corresponding expressions may be similarly obtained for all the planes of the trisoctahedron.

Again, in fig. 30, of the cube with two planes on each edge, and in fig. 31, of the tetrahexahedron bounded by these same planes, the left of the two planes in the front vertical edge of fig. 30 (or the corresponding plane on fig. 31) is parallel to the vertical axis; its intersections with the lateral axes, a and b, are at unequal distances from the centre, expressed by the ratio $2b : 1a$. This ratio for the plane adjoining on the right is $1b : 2a$. The position of the former is expressed by the ratio $ic : 2b : 1a$, and for the other by $ic : 1b : 2a$. Thus, for each of the planes of this tetrahexahedron the ratio between two axes is $1 : 2$, while the plane is parallel to the third axis.

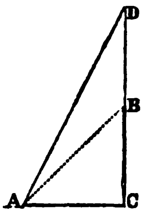
Again, in fig. 22, of the cube with six planes on each solid angle, and in the hexoctahedron in fig. 23, made up of such planes, each of the planes when extended so that it will meet one axis at once its length from the centre, will meet the other axes at distances expressed by a constant ratio, and the expression for the lower right one of the six planes will be $3c : \frac{3}{2}b : 1a$. By a little study, the expressions for the other five adjoining planes can be obtained, and so also those for all the 48 planes of the solid.

In the isometric system the axes a, b, c, are equal, so that in the general expressions for the planes these letters may be omitted; the expressions for the above mentioned forms thus become—

Cube (fig. 1), $i : 1 : i$.
Octahedron (fig. 2), $1 : 1 : 1$.
Dodecahedron (fig. 3), $1 : 1 : i$.
Trapezohedron (fig. 4), $2 : 1 : 2$.
Tetrahexahedron (fig. 5), $i : 1 : 2$.
Trigonal trisoctahedron (fig. 6), $2 : 1 : 1$.
Hexoctahedron (fig. 7), $3 : 1 : \frac{3}{2}$.

Looking again at fig. 17, representing the cube with planes of the trapezohedron, $2 : 1 : 2$, it will be perceived that there might be a trapezohedron having the ratios $1\frac{1}{2} : 1 : 1\frac{1}{2}$, $3 : 1 : 3$, $4 : 1 : 4$, $5 : 1 : 5$, and others; and, in fact, such trapezohedrons occur among crystals. So also, besides the trigonal trisoctahedron $2 : 1 : 1$ (fig. 21), there might be, and there in fact is, another corresponding to the expression $3 : 1 : 1$; and still others are possible. And besides the hexoctahedron $3 : 1 : \frac{3}{2}$ (fig. 23), there are others having the ratios $4 : 1 : 2$, $4 : 1 : \frac{4}{3}$, $5 : 1 : \frac{5}{3}$, and so on.

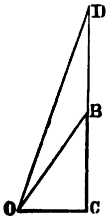
In the above ratios, the number for one of the lateral axes is always made a unit, since only a ratio is expressed; omitting this in the expression, the above general ratios become: for the cube, $i : i$; for the octahedron, $1 : 1$; dodecahedron, $1 : i$; trapezohedron, $2 : 2$; tetrahexahedron, $i : 2$; trigonal-trisoctahedron, $2 : 1$; and hexoctahedron, $3 : \frac{3}{2}$. In the lettering of the figures these ratios are put on the planes, but with the second figure, or *that referring to the vertical* axis, first. Thus the lettering on the hexoctahedron (fig. 23), is $3\text{-}\frac{3}{2}$; on the trigonal trisoctahedron (fig. 21) is 2, the figure 1 being unnecessary; on the tetrahexahedron (fig. 31), $i\text{-}2$; on the trapezohedron (figs. 4 and 19), 2-2; on the dodecahedron (fig. 15), i; on the octahedron, 1; on the cube, $i\text{-}i$, in place of which H is used, the initial of hexahedron. In the printed page these symbols are written with a hyphen in order to avoid occasional ambiguity, thus $3\text{-}\frac{3}{2}$, $i\text{-}2$, 2-2, etc. Similarly, the ratios for all planes, whatever they are, may be written. The numbers are usually small, and never decimal fractions.



The angle between the planes $i\text{-}2$ (or $i : 1 : 2$) and O, in fig. 30, page 21, may be easily calculated, and the same for any plane of the series $i\text{-}n$ ($i : 1 : n$). Draw the right-angled triangle, ADC, as in the annexed figure, making the vertical side, CD, twice that of AC, the base; that is, give them the same ratio as in the axial ratio for the plane. If $AC = 1$, $CD = 2$. Then, by trigonometry, making AC the radius, $1 : R :: 2 : \tan DAC$; or $1 : R :: 2 : \cot ADC$. Whence $\tan DAC = \cot ADC = 2$. By adding to 90°, the angle of the triangle obtained by working the equation, we have the inclination of the basal plane O, or the O on the opposite side of the plane $i\text{-}2$, (faces of the cube) on the plane $i\text{-}2$. So in all cases, whatever the value of n, that value equals the tangent of the basal angle of the triangle (or the cotangent of the angle at the vertex), and from this the inclination to the cubic faces is directly obtained by adding 90°. If $n = 1$, then the ratio is $1 : 1$, as in ACB, and each angle equals 45°, giving 135° for the inclination on either adjoining cubic face.

Again, if the angles of inclination have been obtained by measurement, the value of n in any case may be found by reversing the above calculation; subtracting 90° from the angle, then the tangent of this angle, or the cotangent of its supplement, will equal n, the tangents varying directly with the value of n.

In the case of planes of the $m : 1 : 1$ series (including $1 : 1 : 1$, $2 : 1 : 1$, etc.), the tangents of the angle between a cubic face in the same zone and these planes, less 90°, varies with the value of m. In the case of the plane 1 (or $1 : 1 : 1$), the angle between it and the cubic face is 125° 16′. Subtracting 90°, we have 35° 16′. Draw a right-angled triangle, OBC, with 35° 16′ as its vertex angle. BC has the value of $1c$, or the semi-axis of the cube. Make $DC = 2BC$. Then, while the angle OBC has the value of the inclination on the cubic face less 90° for the plane $1 : 1 : 1$, ODC has the same for the plane $2 : 1 : 1$. Now, making OC the radius, and taking it as unity, BC is the tangent of BOC, or $\cot OBC$. So $DC = 2BC$ is the tangent of DOC, or $\cot ODC$. By lengthening the side CD ($= 2BC$ or $2c$) it may be made equal to $3BC = 3c$, its value in the case of the plane $3 : 1 : 1$; or to $4BC = 4c$, its value in the case of the plane $4 : 1 : 1$; or $mBC = mc$ for any plane in the series $m : 1 : 1$; and since in all there will be the same relation between the vertical and the tangent of the angle at the base (or the cotangent of the angle at the vertex), it follows that the tangent varies with the value of m. Hence, knowing the value of the angle in the case of the form 1 ($1 : 1 : 1$), the others are easily calculated from it.



BC being a unit, the actual value of OC is $\frac{1}{2}\sqrt{2}$, or $\sqrt{\frac{1}{2}}$, it being half the diagonal of a square, the sides of which are 1, and from this value the angle 35° 16′ might be obtained for the angle OBC.

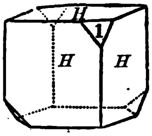
The above law (that for a plane of the $m : 1 : 1$ series, the tangent of its inclination on a cubic face lying in the same zone, less 90°, varies with the value of m, and that it may be calculated for any plane $m : 1 : 1$ from this inclination in the form $1 : 1 : 1$), holds also for planes in the series $m : 2 : 1$, or $m : 3 : 1$, or any $m : n : 1$. That is, given the inclination of O on $1 : n : 1$, its tangent doubled will be that of $2 : n : 1$, or trebled, that of $3 : n : 1$, and so on; or halved, it will be that of the plane $\frac{1}{2} : n : 1$, which expression is essentially the same as $1 : 2n : 2$.

These examples show some of the simpler methods of applying mathematics in calculations under the isometric system. The values of the axes are not required in them, because $a = b = c = 1$.

3. Hemihedral Crystals.—The forms of crystals described above are called *holohedral* forms, from the Greek for *all* and *face*, the number of planes being all that full symmetry requires. The cube has eight *similar* solid angles—*similar, that is, in the enclosing planes and plane angles.* Consequently the law of full symmetry requires that all should have the same planes and the same number of planes; and this is the general law for all the forms. This is a consequence of the equality of the axes and their rectangular intersections.

But in some crystalline forms there are only *half* the number of planes which full symmetry requires. In fig. 39 a cube is represented with an octahedral plane on half, that is, four, of the solid angles. A solid angle having such a plane is diagonally opposite to one without it. The same form is represented in fig. 40, only the cubic faces are the smallest; and in fig. 41 the simple form is shown which is made up of the four octahedral planes. It is a *tetrahedron* or regular three-sided pyramid. If the octahedral faces of fig. 39 had been on the other four of the solid angles of the cube, the tetrahedron made of those planes would have been that of fig. 42 instead of fig. 41.

39.



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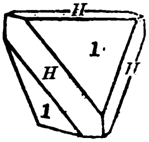

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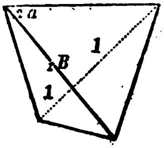

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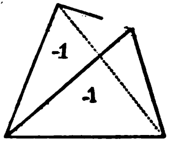
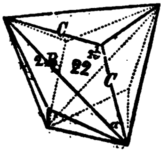


Other hemihedral forms are represented in figs. 43 to 45; fig. 43 is a hemihedral form of the trapezohedron, fig. 4, p. 7; fig. 44, hemihedral of the hexoctahedron, fig. 7, or a hemi-hexoctahedron. Fig. 45 is a combination of the tetrahedron (plane 1) and hemi-hexoctahedron.

43.



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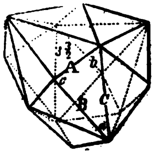

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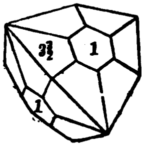
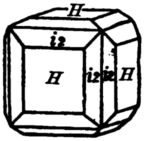


In these forms figs. 41–44, no face has another parallel to it; and consequently they are called *inclined hemihedrons*.

Fig. 46 represents a cube with the planes of a tetrahexahedron, as already explained. In fig. 47, the cube has *only one* of the planes *i*-2 on each edge, and therefore only twelve in all;

and hence it affords an example of hemihedrism—a kind that is presented by many crystals of pyrite. Fig. 48 is the hemihedral form resulting when these twelve planes *i*-2 are extended to the obliteration of the cubic faces; and fig. 49 is another, made of the other twelve of these planes. Again, in fig. 50, a cube is represented having only three out of the six planes of fig. 22, and this is another example of hemihedrism. These kinds differ from the *inclined* hemihedrons in having *opposite parallel faces*, and hence they are called *parallel hemihedrons.*

46.



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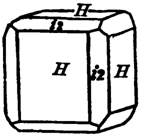

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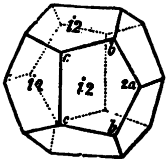

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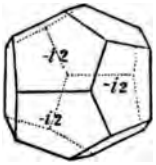

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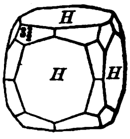


4. Internal Structure of Isometric Crystals, or Cleavage.—

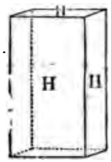
The crystals of many isometric minerals have *cleavage*, or a greater or less capability of division in directions situated symmetrically with reference to the axes. The cleavage directions are parallel either to the faces of the cube, the octahedron, or the dodecahedron. In galenite (p. 145) there is *easy* cleavage in three directions parallel to the faces of the cube; in fluorite (p. 208), in four directions parallel to the faces of the octahedron; in sphalerite (p. 154), in six directions parallel to the faces of the dodecahedron. These cleavages are an important means of distinguishing the species.

The three cubic cleavages are precisely alike in the ease with which cleavage takes place, and in the kinds of surface obtained; and so is it with the four in the octahedral directions, and the six in the dodecahedral. Occasionally cleavages of two of these systems occur in the same mineral; that is, for example, parallel to both the faces of the cube and the octahedron; but when so, those of one system are much more distinct than those of the other, and cleavage surfaces in the two directions are quite unlike as to smoothness and lustre.

5. Irregularities of Isometric Crystals.—

A cube has its faces precisely equal, and so it is with each of the forms represented in figs. 2 to 7. This perfect symmetry is almost never found in actual crystals.

51.



52.

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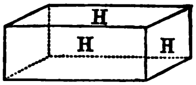
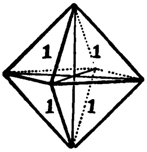


A cubic crystal has generally the form of a square prism (fig. 51 a stout one, fig. 52 another long and slender), or a rectangular prism (fig. 53). In such cases the crystal may still be known to be a cube; because, if so, the kind of surface and kind of lustre on the six faces will be precisely alike; and if there is cubic cleavage it will be exactly equal in facility in three rectangular directions; or if there is cleavage in four, or six, directions, it will be equal in degree in the four, or the six, directions, and have mutual inclinations corresponding with the angles of the octahedron or dodecahedron; and thus the crystal will show that it is isometric in system.

The same shortening or lengthening of the crystal often disguises greatly the octahedron, dodecahedron, and other forms. This is illustrated in the following figures: Fig. 54 shows the

54.



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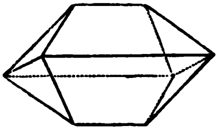

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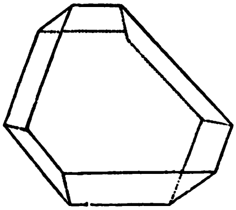

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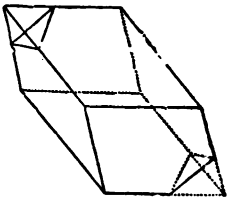
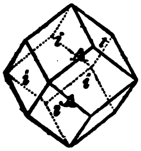


form of the regular octahedron; 55, an octahedron lengthened horizontally; 56, one shortened parallel to one of the pairs of faces; 57, one lengthened parallel to another pair, the ultimate result of which obliterates two of the faces, and places an acute solid angle in place of each. The solid is then six-sided, and has rhombic faces whose plane angles are 120° and 60°. The following figures illustrate corresponding changes in the dodecahedron (fig. 58). In fig. 59 the dodecahedron is lengthened vertically, making a square prism with four-sided pyramidal terminations. In 60, it is shortened vertically. In 61 the dodecahedron is lengthened obliquely in the direction of an octahedral axis, and in 62 it is shortened in the same direction, making six-sided prisms with trihedral terminations.

58.



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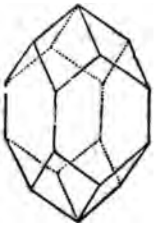

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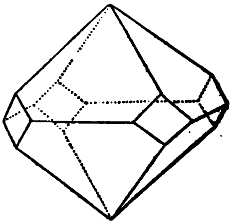

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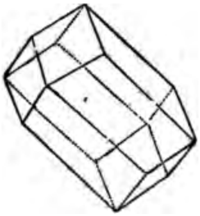

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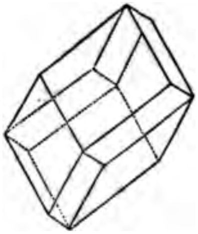
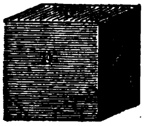


So again in the trapezohedron there are equally deceptive forms arising from elongations and shortenings in the same two directions.

These distortions change the relative sizes of planes, but not the values of angles. In crystals of the several forms represented in figs. 54 to 57, the inclinations are the same as in the regular octahedron. There is the same constancy of angle in other distorted crystals.

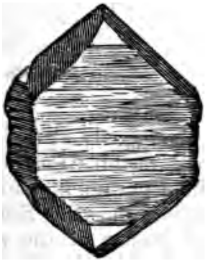
Occasionally, as in the diamond, the planes of crystals are convex; and then, of course, the angles will differ from the true angle. It is important, in order to meet the difficulties in the way of recognizing isometric crystals, to have clearly in the mind the precise aspect of an equilateral triangle, which is the shape of a face of an octahedron; the form of the rhombic face of the dodecahedron; and the form of the trapezoidal face of a trapezohedron. With these distinctly remembered, isometric crystalline forms that are much obscured by distortion, or which show only two or three planes of the whole number, will often be easily recognized.

63.



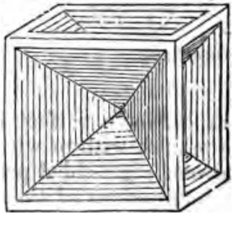
Crystals in this system, as well as in the others, often have their faces striated, or else rough with points. This is generally owing to a tendency in the forming crystal to make two different planes at the same time, or rather an oscillation between the condition necessary for making one plane and that for making another. Fig. 63 represents a cube of pyrite with striated faces. As the faces of a cube are equal, the striations are alike on all. It will be noted that the striations of adjoining faces are at right angles to one another. The little ridges of the striated surfaces are made up of planes of the pentagonal dodecahedron (fig. 49, p. 26), and they arise from an oscillation in the crystallizing conditions between that which, if acting alone, would make a cube, and that which would make this hemihedral dodecahedron. Again, in magnetite, oscillations between the octahedron and dodecahedron produce the striations in fig. 64.

64.



MAGNETITE.

65.



COMMON SALT.

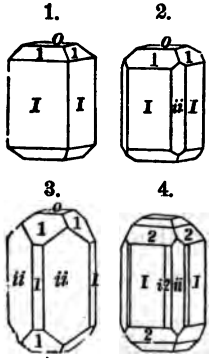
Octahedral crystals of fluorite often occur with the faces made up of evenly projecting solid angles of a cube, giving them rough instead of polished planes. This has arisen from oscillation between octahedral and cubic conditions.

In some cases crystals are filled out only along the diagonal planes. Fig. 65 represents a crystal of common salt of this kind, having pyramidal depressions in place of the regular faces. Octahedrons of gold sometimes occur with three-sided pyramidal depressions in place of the octahedral faces. Such forms sometimes result when crystals are eroded by any cause.

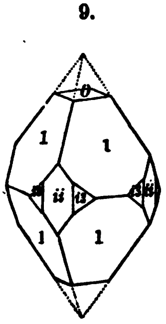
II. DIMETRIC, OR TETRAGONAL SYSTEM.

1. Descriptions of Forms.—In this system (1) the axes cross at right angles; (2) the vertical axis is either longer or shorter than the lateral; and (3) the lateral axes are equal.

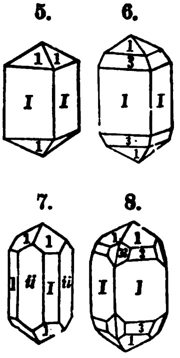
The following figures represent some of the crystalline forms. They are very often attached by one extremity to the support of rock and have perfect terminating planes only at the other. Square prisms, with or without pyramidal terminations, square octahedrons, eight-sided prisms, eight-sided pyramids, and especially combinations of these, are the common forms. Since the lateral axes are equal, the four lateral planes of the square prisms are alike in lustre and surface-markings. For the same reason the symmetry of the crystal is throughout by fours; that is, the number of similar pyramidal planes at the extremity is either four or eight; and they show that they are similar by



IDOCRASE.



APOPHYLLITE.

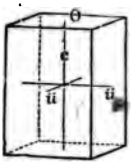


ZIRCON.

being exactly alike in inclination to the basal plane as well as alike in lustre.

There are two distinct square prisms. In one (fig. 10) the

10.



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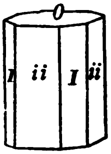

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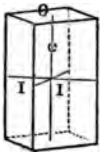

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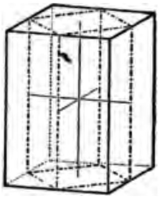


axes connect the centres of the lateral faces. In the other (fig. 12) they connect the centres of the lateral edges. In fig. 11 the two prisms are combined; the figure shows that the planes of one truncate the lateral edges of the other, the interfacial angle between adjoining planes being 135°. Figs. 2, 3, 4, 7, are of others having planes of both prisms. In fig. 13 one prism is represented within the other.

Fig. 14 represents an eight-sided prism, and fig. 15 a combination of a square prism (*i*-*i*) with an eight-sided prism (*i*-2)

14.

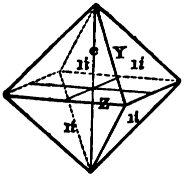
15.

Another example of this is shown in fig. 4, and also in fig. 9, the planes *i*-2 in one, and *i*-3 in the other.

The basal plane in these prisms is an independent plane, because the vertical axis is not equal to the lateral, and hence it almost always differs in lustre and smoothness from the lateral.

Like the square prisms, the square octahedrons are in two series, one set (fig. 16) having the lateral or basal edges parallel to the lateral axes, and these axes connecting the centres of opposite basal edges, and the other (fig. 17) having them diagonal to the axes, these axes connecting the apices of the opposite solid angles, as in the isometric octahedron. There may be, on the same crystal, faces of several octahedrons of these two series, differing in having their planes inclined at different angles to the basal plane. In figs. 5 and 7 there is one of these pyramids terminating the prism, and in figs. 6 and 8 the planes of two. In figs. 1 to 3 there are planes of the same octahedron, but combined with the basal plane *O*; and in fig. 4 there are planes of two, with *O*. In fig. 9 there are planes of the same octahedron, with planes of a square prism (*i-i*), and of an eight-sided prism (*i-2*). In fig. 18 there is the prism *i-i* combined with two octahedrons, and the basal plane *O*; and in 19 the planes of one octahedron with the prism *I*.

16.



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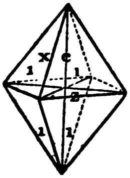

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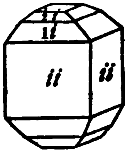

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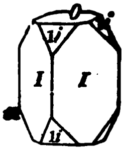
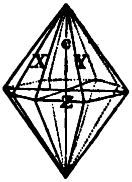


Fig. 20 represents an eight-sided double pyramid, made of equal planes, equally inclined to the base; and fig. 21, the same planes on the square prism *i-i*. The small planes, in pairs, on fig. 8, are of this kind. In fig. 22 the small planes 3-3 of fig. 8 occur alone, without planes of the four-sided pyramids, and therefore make the eight-sided pyramid, 3-3.

20.



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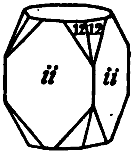

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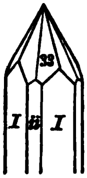
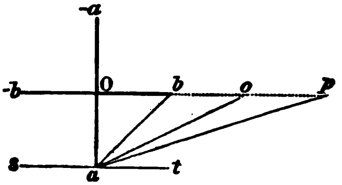


This solid of sixteen planes has the largest number of similar planes possible in the dimetric system, while the largest number in the isometric system (occurring in the hexoctahedron) is forty-eight.

2. Positions of the Planes with reference to the Axes.—*Lettering of planes.* In the prism fig. 10, the lateral planes are parallel to the vertical axis and to one lateral axis, and meet the other lateral axis at its extremity. The expression for it is hence (c standing for the vertical axis and a, b for the lateral) $ic : ib : 1a$, i, as before, standing for infinity and indicating parallelism. For the prism of fig. 12, the prismatic planes meet the two lateral axes at their extremities, and are parallel to the vertical, and hence the expression for them is $ic : 1b : 1a$. In the annexed figure the two bisecting lines, a —a and b —b, represent the lateral axes; the line $s\ t$ stands for a section of a lateral plane of the first of these prisms, it being parallel to one lateral axis and meeting the other at its extremity, and ab for that of the other, it meeting the two at their extremities.

23.



In the eight-sided prisms (figs. 14, 15), each of the lateral planes is parallel to the vertical axis, meets one of the lateral axes at its extremity, and would meet the other axis if it were prolonged to two or three or more times its length. The line ao, in fig. 23, has the position of one of the eight planes; it meets the axis b at o, or twice its length from the centre; and hence the expression for it would be $ic : 2b : 1a$, or, since $b = a$, $ic : 2 : 1$, which is a general expression for each of the eight planes. Again, ap has the position of one of the eight planes of another such prism; and since Op is three times the length of Ob, the expression for the plane would be $ic : 3 : 1$. So there may be other eight-sided prisms; and, putting n for any possible ratio, the expression $ic : n : 1$ is a general one for all eight-sided prisms in the dimetric system.

A plane of the octahedron of fig. 16 meets one lateral axis at its extremity, and is parallel to the other, and it meets the vertical axis c at its extremity; its expression is consequently (dropping the letters a and b, because these axes are equal) $1c : i : 1$. Other octahedrons in the same vertical series may have the vertical axis longer or shorter than axis c; that is, there may be the planes $2c : i : 1$, $3c : i : 1$, $4c : i : 1$, and so on; or $\frac{1}{3}c : i : 1$, $\frac{1}{2}c : i : 1$, and so on; or, using m for any coefficient of c, the expression becomes general, $mc : i : 1$. When $m = 0$ the vertical axis is zero, and the plane is the basal plane O of the prism; and when $m =$ infinity, the plane is $ic : i : 1$, or the vertical plane of the prism in the same series, $i\text{-}i$, fig. 10.

The planes of the octahedron of fig. 17 meet two lateral axes at their extremities, and the vertical at its extremity, and the expression for the plane is hence $1c : 1 : 1$. Other octahedrons in this series will have the general expression $mc : 1 : 1$, in which m may have any value, not a decimal, greater or less than unity, as in the preceding case. When in this series $m =$ infinity, the plane is that of the prism $ic : 1 : 1$, or that of fig. 12.

In the case of the double eight-sided pyramid (figs. 20, 21, 22), the planes meet the two lateral axes at *unequal* distances from the centre; and also meet the vertical axis. The expression may be

$2c : 2 : 1$, $4c : 2 : 1$, $5c : 3 : 1$, and so on; or, giving it a general form, $mc : n : 1$.

In the lettering of the planes on figures of dimetric crystals, the first number (as in the isometric and all the other systems) is the coefficient of the vertical axis, and the other is the ratio of the other two, and when this ratio is a unit it is omitted.

The expressions and the lettering for the planes are then as follows:

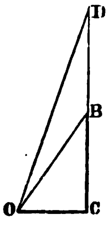
		Expressions.	Lettering.
For square prisms	1.	$ic : i : 1$	i-i
	2.	$ic : 1 : 1$	i or I.
For eight-sided prisms.........		$ic : n : 1$	i-n
For octahedrons...........	1.	$mc : i : 1$	m-i
	2.	$mc : 1 : 1$	m
For double eight-sided pyramids,		$mc : n : 1$	m-n

The symbols are written without a hyphen on the figures of crystals. On figure 14, the plane i-n is that particular i-n in which $n = 2$, or i-2. In fig. 21 the planes of the double eight-sided pyramid, m-n, have $m = 1$ and $n = 2$ (the expression being $1 : 2 : 1$), and hence it is lettered 1-2. In fig. 8 and in fig. 22 it is the one in which $m = 3$ and $n = 3$ (the expression being $3 : 3 : 1$), and hence the lettering 3-3.

The length of the vertical axis c may be calculated as follows, provided the crystal affords the required angles:

Suppose, in the form fig. 18, the inclination of O on plane 1-i to have been found to be 130°, or of i-i on the same plane, 140° (one follows from the other, since the sum of the two, as has been explained, is necessarily 270°). Subtracting 90°, we have 40° for the inclination of the plane on the vertical axis c, or 50° for the same on the lateral axis a, or the basal section. In the right-angled triangle, OBC, the angle OBC equals 40°. If OC be taken as $a = 1$, then BC will be the length of the vertical axis c; and its value may be obtained by the equation $\cot 40° = BC$, or $\tan 50° = BC$.

24.



On fig. 18 there is a second octahedral plane, lettered $\frac{1}{2}$-i, and it might be asked, Why take one plane rather than the other for this calculation? The determination on this point is more or less arbitrary. It is usual to *assume* that plane as the unit plane in one or the other series of octahedrons (fig. 16 or fig. 17) which is of most common occurrence, or that which will give the simplest symbols to the crystalline forms of a species; or that which will make the vertical axis nearest to unity; or that which corresponds to a cleavage direction.

The value of the vertical axis having been thus determined from 1-i, the same may be determined in like manner for $\frac{1}{2}$-i in the same figure (fig. 18). The result would be a value just half that of BC. Or if there were a plane 2-i, the value obtained would be twice BC, or BD in fig. 24; the angle $ODC + 90°$ would equal the inclination of O on 2-i. So for other planes in the same vertical zone, as 3-i, 4-i, or any plane m-i.

If there were present several planes of the series m-i, and their inclinations to the basal plane O were known, then, after subtracting from the values 90°, the cotangents of the angles obtained, or the tangents of their complements, will equal m in each case; that is, the tangents (or cotangents) will vary directly with the value of m. The logarithm of the tangent for the plane 1-*i*, added to the logarithm of 2, will equal the logarithm of the tangent for the plane 2-*i*, and so on.

The *law of the tangents* for this vertical zone *m-i* holds for the planes of all possible vertical zones in the dimetric system. Further, if the square prism were laid on its side so that one of the lateral planes became the base, and if zones of planes are present on it that are vertical with reference to this assumed base, the law of the tangents still holds, with only this difference to be noted, that then one of the lateral axes is the vertical. It holds also for the *trimetric* system, no matter which of the diametral planes is taken for the base, since all the axial intersections are rectangular. It holds for the *monoclinic* system for the zone of planes that lies between the axes c and b and that between the axes a and b, since these axes meet at right angles, but not for that between c and a, the angle of intersection here being oblique. It holds for all vertical zones in the *hexagonal* system, since the basal plane in this system is at right angles to the vertical axis. But it is of no use in the *triclinic* system, in which all the axial intersections are oblique.

The value of the vertical axis c may be calculated also from the inclination of O on 1, or of I on 1. See fig. 2, and compare it with fig. 17. If the angle I on 1 equals 140°, then, after subtracting 90°, we have 50° for the basal angle in the triangle OCB, fig. 24; or for half the interfacial angle over a basal edge—edge Z—in fig. 17. The value of c may then be calculated by means of the formula

$$c = \tan \tfrac{1}{2} Z \sqrt{\tfrac{1}{2}},$$

by substituting 50° for $\frac{1}{2}Z$ and working the equation.

For any octahedron in the series m, the formula is

$$mc = \tan \tfrac{1}{2} Z \sqrt{\tfrac{1}{2}}$$

Z being the angle over the basal edge of that octahedron. If $m = 2$, then $c = \frac{1}{2} (\tan \frac{1}{2}Z \sqrt{\frac{1}{2}})$. Further, $m = (\tan \frac{1}{2}Z \sqrt{\frac{1}{2}}) \div c$.

The interfacial angle over the terminal edge of any octahedron m may be obtained, if the value of c is known, by the formulas

$$mc = \cot \epsilon \qquad \cos \epsilon = \cot \tfrac{1}{2} X$$

X being the desired angle (fig. 17). The same for any octahedron *m-i* may be calculated from the formulas

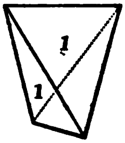
$$mc = \cot \epsilon \qquad \cos \epsilon = \cos \tfrac{1}{2} Y \sqrt{2}$$

Y being the desired angle (fig. 16).

For other methods of calculation reference may be made to the "Text Book of Mineralogy," or to some other work treating of mathematical crystallography.

3. Hemihedral Forms.—Among the few hemihedral forms under the dimetric system there is a tetrahedron, called a sphenoid (figs. 25 or 26), and also forms in which only half of the sixteen planes of the double eight-sided pyramid, or half the eight planes of an eight-sided prism—those alternate in position

25.



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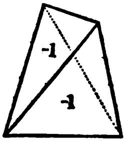

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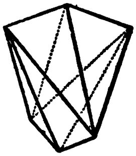

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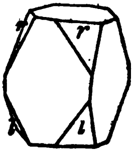


—are present (figs. 27, 28). In fig. 27 the absent planes are those of half the *pairs* of planes; and in fig. 28 they include one of each of the pairs, as will be seen on comparing these figures with fig. 21.

4. **Cleavage.**—In this system cleavage may occur parallel to the sides of either of the square prisms; parallel to the basal plane; parallel to the faces of a square octahedron; or in two of these directions at the same time. Cleavage parallel to the base and that parallel to a prism are never equal, so that such prisms need not be confounded with distorted cubes.

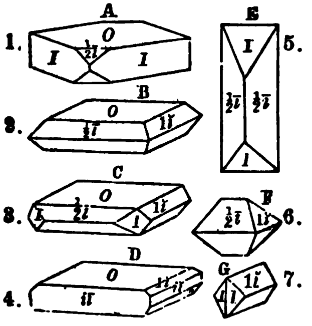
5. **Irregularities in Crystals.**—The square prisms are very often rectangular instead of square, and so with the octahedrons. But, as elsewhere among crystals, the angles remain constant. When forms are thus distorted, the four prismatic planes will have like lustre and surface markings, and thus show that the faces are normally equal and the lateral axes therefore equal. If the plane truncating the edge of a prism makes an angle of precisely 135° with the faces of the prism, this is proof that the prism is square, or that the lateral axes are equal, since the angle between a diagonal of a square and one of its sides is 45°, and 135° is the supplement of 45°.

6. **Distinctions.**—The dimetric prisms have the base different in lustre from the sides, and planes on the basal edges different in angle from those on the lateral, and thus they differ from isometric forms. The lateral edges may be truncated, and the new plane will have an angle of 135° with those of the prism, in which they differ from trimetric forms, while like isometric. The extremities of the prism, if it have any planes besides the basal, will have them in fours or eights, each of the four, or of the eight, inclined to the base at the same angle. When there is any cleavage parallel to the vertical axis, it is alike

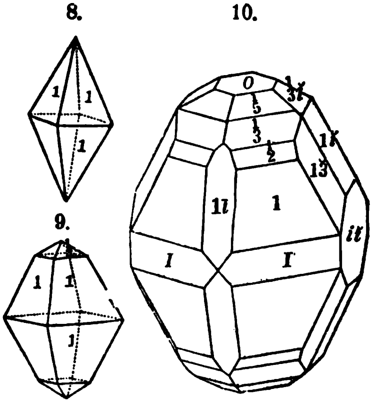
in two directions at right angles with one another. The lateral planes of either square prism are alike in lustre and markings.

III. TRIMETRIC, OR ORTHORHOMBIC SYSTEM.

1. Descriptions of Forms.—The crystals under the trimetric system vary from rectangular to rhombic prisms and rhombic octahedrons, and include various combinations of such forms. Figs. 1 to 7 are a few of those of the species barite, and figs. 8 to 10 of crystals of sulphur.



BARITE.



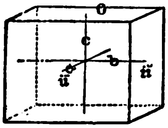
SULPHUR.

Fig. 11 represents a rectangular prism (diametral prism), and fig. 12 a rhombic prism, each with the axes. The axes connect the centres of the opposite planes in the former; but in the latter the lateral axes connect the centres of the opposite edges. Of the two lateral axes the longer is called the *macrodiagonal*, and the shorter the *brachydiagonal*. The vertical section containing the former is the *macrodiagonal section* and that containing the latter, the *brachydiagonal section*.

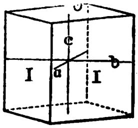
In the rectangular prism, fig. 11, only opposite planes are alike, because the three axes are unequal. Of these planes, that opposite to the larger lateral axis is called the *macropinacoid*, and that opposite the shorter the *brachypinacoid* (from the Greek for long and short, and a word signifying *board* or *table*). Each pair—that is, one of these planes and its opposite—is called a hemiprism.

In the rhombic prism, fig. 12, the four lateral planes are similar planes. But of the four lateral edges of the prism two are obtuse and two acute. Fig. 13 represents a combination of the rectangular and rhombic prisms, and illustrates the relations of their planes. Other rhombic prisms parallel to the vertical axis occur, differing in interfacial angles, that is, in the ratio of the lateral axes.

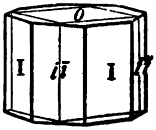
11.



12.



13



Besides *vertical* rhombic prisms, there are also horizontal prisms parallel to each lateral axis, *a* and *b*. In fig. 2 the narrow planes in front (lettered $\frac{1}{2}\bar{\imath}$) are planes of a rhombic prism parallel to the *longer* of the lateral axes, and those to the right ($1\breve{\imath}$) are planes of another parallel to the shorter lateral axis. In fig. 6 the planes are those of these two horizontal prisms. Such prisms are called also *domes*, because they have the form of the roof of a house (*domus* in Latin meaning *house*). In fig. 3 these same two domes occur, and also the planes (lettered *I*) of a *vertical* rhombic prism. Of these domes there may be many both in the macrodiagonal and the brachydiagonal series, differing in angle (or in ratio of the two intersected axes). Those parallel to the longer lateral axis, or the macrodiagonal, are called *macrodomes*; and those parallel to the shorter, or brachydiagonal, are called *brachydomes*.

A rhombic octahedron, lettered 1, is shown in fig. 8; a combination of two, lettered 1 and $\frac{1}{3}$, in fig. 9; and a combination of four, lettered 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, in fig. 10. This last figure contains also the planes *I*, or those of a vertical rhombic prism; the planes $1\text{-}\bar{\imath}$, or those of a dome parallel to the *longer* lateral axis; the planes $1\text{-}\breve{\imath}$, or those of a dome parallel to the *shorter* lateral axis; the plane *O*, or the basal plane; the plane $i\text{-}\breve{\imath}$, or the brachypinacoid; and also a rhombic octahedron lettered $1\text{-}\breve{3}$.

2. Positions of Planes. Lettering of Crystals.—The notation is, in a general way, like that of the dimetric system, but with differences made necessary by the inequality of the lateral axes. The letters for the three are written $c : \bar{b} : \breve{a}$; $\bar{b}$ being the longer lateral and $\breve{a}$ the shorter lateral. In place of the square prism of the dimetric system, $i\text{-}i$, there are the hemiprisms $i\text{-}\bar{i}$ and $i\text{-}\breve{i}$, or the macropinacoid and brachypinacoid, having the expressions $ic : i\bar{b} : 1\breve{a}$ and $ic : 1\bar{b} : i\breve{a}$. The form I is the rhombic prism, having the expression $ic : 1\bar{b} : 1\breve{a}$, corresponding to the square prism I in the dimetric system. The planes $i\text{-}\bar{n}$ or $i\text{-}\breve{n}$ are other rhombic vertical prisms, the former corresponding to $ic : n\bar{b} : 1\breve{a}$, the other to $ic : 1\bar{b} : n\breve{a}$. If $n = 2$, the plane is lettered either $i\text{-}\bar{2}$ or $i\text{-}\breve{2}$. The plane $1\text{-}\breve{3}$ has the expression $1c : 1\bar{b} : 3\breve{a}$. $m\text{-}\bar{n}$ and $m\text{-}\breve{n}$ comprise all possible rhombic prisms and octahedrons, and correspond to the expressions $mc : n\bar{b} : 1\breve{a}$ and $mc : 1\bar{b} : n\breve{a}$. When $m =$ infinity they become $i\text{-}\bar{n}$ and $i\text{-}\breve{n}$, or expressions for vertical rhombic prisms; when $n =$ infinity they become $m\text{-}\bar{i}$ and $m\text{-}\breve{i}$, or expressions for macrodomes and brachydomes.

The question which of the three axes should be taken as the vertical axis is often decided by reference simply to mathematical convenience. Sometimes the crystals are prominently prismatic only in one direction, as in topaz, and then the axis in this direction is made the vertical. In many cases a cleavage rhombic prism, when there is one, is made the vertical, but exceptions to this are numercus. There is also no general rule for deciding which octahedron should be taken for the unit octahedron. But however decided, the axial relations for the planes will remain essentially the same. In fig. 10, had the plane lettered $\frac{1}{2}$ been made the plane 1, then the series, instead of being as it is in the figure, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, would have been 2, 1, $\frac{2}{3}$, $\frac{2}{5}$, in which the mutual axial relations are the same.

The relative values of the axes in the trimetric system may be calculated in the same way as that of the vertical axis in the dimetric system, explained on page 34. The law of the tangents, as stated on page 35, holds for this system.

3. Hemihedral Forms.—Hemihedral forms are not common in this system. Some of those so considered have been proved to owe their apparent hemihedrism to their being of the monoclinic system, as in the case of datolite and two species of the chondrodite group. In a few kinds, as, for example, calamine, one extremity of a crystal differs in its planes from the other. Such forms are termed *hemimorphic*, from the Greek for *half* and *form*. They become polar electric when heated, that is, are pyroelectric, showing that this hemimorphism is connected with polarity in the crystal.

4. Cleavage.—Cleavage may take place in the direction of either of the diametral planes (that is, either face of the rectangular prism); but it will be different in facility and in the surface afforded for each. In anhydrite, however, the difference is very small. Cleavage may also occur in the direction of the planes of a rhombic prism, either alone or in connection with cleavage in other directions. It also sometimes occurs, as in sulphur, parallel to the faces of a rhombic octahedron.

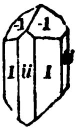
5. Irregularities in Crystals.—The crystals almost never correspond in their diametral dimensions with the calculated axial dimensions. They are always lengthened, widened, shortened, or narrowed abnormally, but without affecting the angles. Examples of diversity in this kind of distortion are given in figs. 1 to 7, of barite.

6. Distinctions.—In the trimetric system the angle 135° does not occur, because the three axes are unequal. There are pyramids of four similar planes in the system, but never of eight; and the angles over the terminal edges of the pyramids are never equal as they are in the dimetric system. The rectangular octahedron of the trimetric system is made up of two horizontal prisms, as shown in fig. 6, and is therefore not a simple form; and it differs from the octahedron of the dimetric system corresponding to it (fig. 16, p. 32) in having the angles over the basal edges of two values.

IV. MONOCLINIC SYSTEM.

1. Descriptions of Forms.—In this system the three axes are unequal, as in the trimetric system; but one of the axial intersections is oblique, that between the axis *a* and the vertical axis *c*. The following examples of its crystalline forms, figs. 1 to 6, show the effect of this obliquity. On account of it the front or back planes above and below the middle in these figures differ, and the anterior and posterior prismatic planes are unequally inclined to a basal plane.

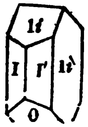
1.



2.

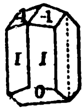
PYROXENE.

3.



FELDSPAR.

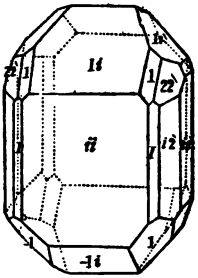
4.



HORNBLENDE.

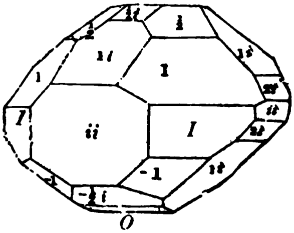
The axes and their relations are illustrated in figs. 7 and 8. Fig. 7 represents an oblique rectangular prism, and fig. 8 an oblique rhombic. The former is the diametral prism, like the rectangular of the trimetric system. The axes connect the centres of the opposite faces, and the planes are of three distinct kinds, being parallel to unlike axes and diametral sections. In the latter, as in the trimetric rhombic prism, the lateral axes connect the centres of the opposite sides. Moreover, this rhombic prism may be reduced to the rectangular by the removal of its edges by planes parallel to the lateral axes.

5.



MONAZITE.

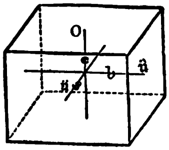
6.



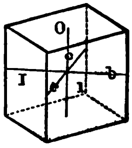
MIRABILITE.

The axis *a*, or the inclined lateral axis (inclined at an oblique angle to the vertical axis *c*), is called the *clinodiagonal*; and the axis *b*, which is not inclined, the *orthodiagonal* (from the Greek for *right*, or rectangular). The vertical section through the former is called the *clinodiagonal section*; it is parallel to the plane *i-ì* (fig. 1–6). The vertical section through the latter is the *orthodiagonal section*; it is parallel to planes *i-ī*. Owing to the oblique angle between *a* and *c*, the planes above *a* differ in their relations to the axes from those below, and hence comes the difference in the angle they make with the basal plane.

7.



8.



The halves of a crystal either side of the clinodiagonal section —the vertical section through *a* and *c*—*are alike in all planes and angles.* Another important fact is this: that the plane *i-ì*, or that parallel to the clinodiagonal section, is at *right angles* not only to *O* and *i-ī*, but to all planes in the zone of *O* and *i-ī*.

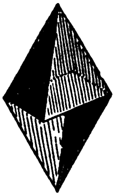
that is, in the clinodiagonal zone; and this is a consequence of the right angle which axis *b* makes with both axis *c* and axis *a*. The plane *i-i* is called the *orthopinacoid*, it being parallel to the orthodiagonal; and the plane *i-ì*, the *clinopinacoid*, it being parallel to the clinodiagonal.

Vertical rhombic prisms have the same relations to the lateral axes as in the trimetric system. Domes, or horizontal rhombic prisms, occur in the orthodiagonal zone, because the vertical axis *c* and the orthodiagonal *b* make right angles with one another. In fig. 6 the planes 1-*ì*, 2-*ì* belong to two such domes. They are called *clinodomes*, because parallel to the clinodiagonal.

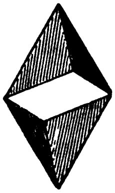
In the clinodiagonal zone, on the contrary, the planes above and below the basal plane differ, as already stated, and hence there can be no orthodomes; they are *hemiorthodomes*. Thus, in fig. 6, ½-*i*, 1-*i* are planes of hemiorthodomes above *i-i*, and −½-*i* is a plane of another of different angle below *i-i*. The plane, *and its diagonally opposite*, make the hemiorthodome.

The octahedral planes above the plane of the lateral axes also differ from those below. Thus, in figs. 5 and 6, the planes 1, 1 are, in their inclinations, different planes from the planes −1, −1; so in all cases. Thus there can be no monoclinic octahedrons—only *hemioctahedrons*. An oblique octahedron is made up of two sets of planes; that is, planes of two hemioctahedrons. Such an octahedron may be modelled and figured, but it will consist of two sets of planes: one set including the two above the basal section in front and their diagonally opposites behind (fig. 9), and the other set including the two below the basal section and their diagonally opposites (fig. 10).

9.



10.



A hemioctahedron, since it consists of only four planes, is really an obliquely placed rhombic prism, and very frequently they are so lengthened as to be actual prisms.

2. Positions of Planes. Lettering of Crystals.—On account of the obliquity of the crystals, the planes above and below the basal section require a distinguishing mark in their lettering, as well as in the mathematical expressions for them. One set is made *minus* and the other *plus*. The plus sign is omitted in the lettering. In fig. 7 there are above the basal section (or above $i\text{-}i$) the planes $1\text{-}i$, $\frac{1}{2}\text{-}i$, 1, $\frac{1}{2}$, but below it, $-\frac{1}{2}\text{-}i$, -1. The *plus* planes are those opposite the acute intersection of the basal and orthodiagonal sections, and the *minus* those opposite the obtuse. No signs are needed for planes of the clinodiagonal section, since they are alike both above and below the basal section.

The distinction of longer and shorter lateral axis is not available in this system, since either may be the clinodiagonal. The distinction of clinodiagonal and orthodiagonal planes is indicated by a grave accent over the number or letters referring to the clinodiagonal. The lettering for the clinodomes on fig. 6 is $1\text{-}\grave{i}$, $2\text{-}\grave{i}$—the $\grave{i}$ (initial of infinite, with the accent) signifying parallelism to the *clino*diagonal. The hemioctahedrons, 1, 2, etc., need no such mark, as the expression for them is $1c : 1b : 1\grave{d}$, $2c : 1b : 1\grave{d}$, the planes having a unit ratio for $\grave{d}$ and b. But the plane $2\text{-}\grave{2}$, in fig. 5, requires it, its expression being $2c : 1b : 2\grave{d}$; the fact that the last 2 refers to the clinodiagonal is indicated by the accent. If it referred to the orthodiagonal, that is, if the expression for the plane were $2c : 2b : 1\grave{d}$, it would be written 2-2 without the accent.

3. Cleavage.—Cleavage may be basal, or parallel to either of the other diametral sections, or parallel to a vertical rhombic prism, or to the planes of a hemioctahedron; or to the planes of a clinodome, or to that of a hemiorthodome. If occurring in two or more directions in any species it is always different in degree in each different direction, as in all the other systems.

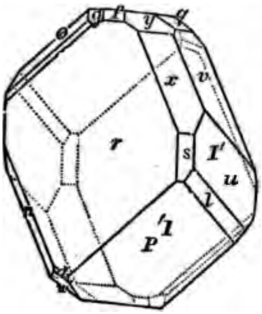
4. Irregularities.—Crystals of this system may be elongated abnormally in the direction of either axis, and any diagonal. The hemiorthodomes may be in aspect the bases of prisms, and the hemioctahedrons the sides of prisms. Which plane in the zone of hemiorthodomes should be made the base, and which in the series of hemioctahedrons should be assumed as the fundamental prism determining the direction of the vertical axis, is often decided differently by different crystallographers. Convenience of mathematical calculation is often the principal point referred to in order to reach a conclusion.

V. TRICLINIC SYSTEM.

1. Descriptions of Forms.—In the triclinic system the three axes are unequal and their three intersections are oblique, and consequently there are never more than two planes of a kind;

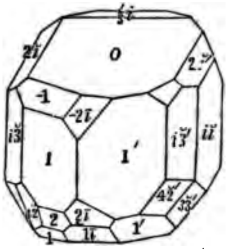
that is, planes having the same inclinations to either diametral section. The following are examples:

1.



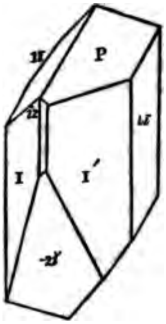
AXINITE.

2.



ANORTHITE.

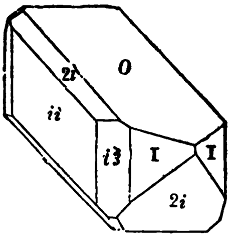
3.



AMBLYGONITE.

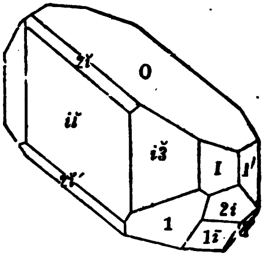
The difference in angle from monoclinic forms is often very small. This is true in the Feldspar family. Fig. 2, of the feldspar called anorthite, is very similar in general form to fig. 4, of orthoclase, which is monoclinic. This is still more strikingly seen on comparing fig. 4 with fig. 5, representing a crystal of oligoclase, another one of the triclinic feldspars. The planes on the two are the same with one exception; but there is this difference, that in orthoclase, as in all monoclinic crystals, the angle between the planes *O* and *i-ī* (the two directions

4.



ORTHOCLASE.

5.



OLIGOCLASE.

of cleavage) is 90°; and in oligoclase and the other triclinic feldspars it is 3° to 5° from 90°, being in oligoclase 93° 50′, and in anorthite 94° 10′. This difference in angle involves oblique intersections between the axes *b* and *c*, and *c* and *a*, which are rectangular in monoclinic forms. There is a similarly close relation between the triclinic form of rhodonite and that of pyroxene, and a resemblance also in composition.

The diametral prism in this system is similar to fig. 7 on page 41, under the monoclinic system, but differs in having the planes all rhomboidal instead of part rectangular. The form corresponding to the oblique rhombic prism of the monoclinic system (fig. 8, p. 41) also has rhomboidal instead of rhombic planes; moreover, the two prismatic planes have unequal inclinations to the vertical diametral section, and are therefore dissimilar planes. The prism, consequently, is made of two hemiprisms, and the basal plane is another, making in all three hemiprisms.

2. Cleavage.—Cleavage takes place independently in different diametral or diagonal directions. In the triclinic feldspars it conforms to the directions in orthoclase, with only the exception arising from the obliquity above explained.

VI. HEXAGONAL SYSTEM.

This system is distinguished from the others by the character of its symmetry—the number of planes of a kind around the vertical axis being a multiple of 3. The number of *lateral* axes is hence 3. It is related to the dimetric system in having the lateral axes at right angles to the vertical and equal, and is hence like it also in the optical characters of its crystals. Its hexagonal prismatic form approaches trimetric crystals in the obtuse angle (120°) of the prism, some trimetric crystals having an angle of nearly 120°.

Under this system there are two sections:

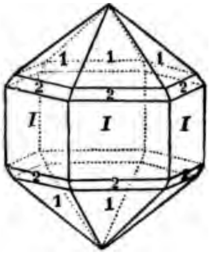
1. The HEXAGONAL SECTION, in which the number of planes of a kind around each vertical axis above or below the basal section is 6 or 12.

2. The RHOMBOHEDRAL SECTION, in which the number of planes of a kind around each half of the vertical axis, above or below the basal section, is 3 or 6; and, in addition, the planes above are alternate in position with those below. The forms are *mathematically* hemihedral to the hexagonal, but not so in their real nature.

I. HEXAGONAL SECTION.

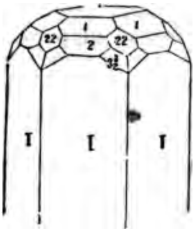
1. Description of Forms.—Figs. 1 to 3 represent some of the forms under this section. Figs. 2 and 3 show only one extremity; and such crystals are seldom perfect at both. All exhibit well the symmetry *by sixes* which characterizes this section of the hexagonal system.

1.



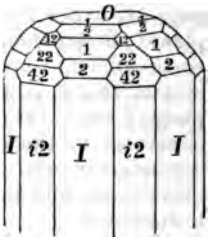
MIMETITE.

2.



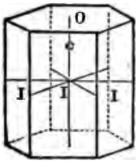
BERYL.

3.

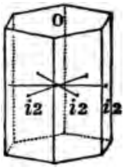


APATITE.

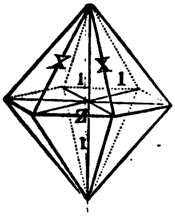
4.



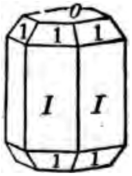
5.



6.



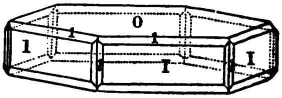
7.



Prisms. Under this system there are two hexagonal prisms and a number of occurring twelve-sided prisms. Fig. 4 represents one of the hexagonal prisms, with its axes—the three lateral connecting the centres of the opposite edges. The lateral angles of the prism are 120°. If the lateral edges of this prism are truncated, as in the figure of apatite (fig. 3), the truncating planes, *i*-2, are the lateral faces of another similar hexagonal prism, in which, as the relations of the two show, the lateral axes connect the centres of the opposite lateral faces. This prism is represented in fig. 5.

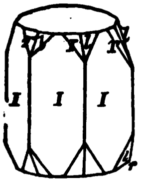
The lateral edges of the hexagonal prisms occur sometimes with two similar planes on each edge, and these planes, when extended to the obliteration of the hexagonal prism, make a *twelve-sided* prism. These two planes are seen in fig. 8, along with the planes *I* of the hexagonal prism, and 1 of a double six-sided pyramid, besides the basal plane *O*.

8.



Double pyramids. The double pyramids are of three kinds: (1) A series of six-sided, whose planes belong to the same vertical zone with the planes *I*. The planes of two such pyramids (lettered 1, 2) are shown in figs. 1 and 2, three of them in fig. 3 (lettered ½, 1, 2), and one in fig. 7, and one such double pyramid, without combination with other planes, in fig. 6. (2) A series of six-sided double pyramids, whose planes are in the same vertical zone with *i*-2, examples of which occur on fig. 2 (plane 2-2)—on fig. 3 (planes 1-2, 2-2, 4-2). The form of this double pyramid is like that represented in fig. 6, but the lateral axes connect the centres of the basal edges. The double six-sided pyramid is sometimes called a *quartzoid*, because it occurs in quartz. (3) Twelve-sided double pyramids. Two planes of such a pyramid are shown on a hexagonal prism in fig. 9, also in fig. 2 (the planes 3-$\frac{3}{2}$), and the simple form consisting of such planes in fig. 10—a form called a *berylloid*, as the planes are common in beryl. In fig. 11 the planes 1 belong to a double six-sided pyramid; and those next below (of which three are lettered W) to a double twelve-sided pyramid.

9.



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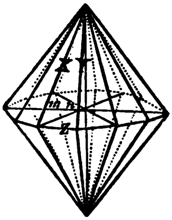

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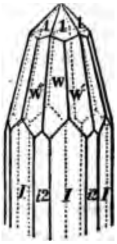
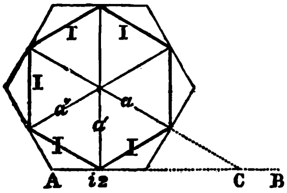


2. Lettering of Crystals.—The prism of fig. 5 is lettered *i*-2, because it is parallel to the vertical axis, and has the ratio of 1 : 2 between two lateral axes. This is shown in the annexed figure, which represents the hexagonal outline of the prism *i*-2 circumscribing that of the prism *I*. The plane *i*-2 is produced to meet axis *a*, which it does when *a* is extended to *twice its length;* whence the ratio for the axes *a*, *a'*, is 1 : 2.

12.



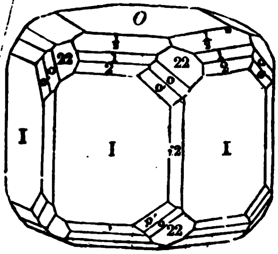
The numbers 1, 2, on the double hexagonal pyramids in fig. 1 indicate the relative lengths of the vertical axis of the two pyramids, they having the same 1 : 1 ratio of the lateral axes; and so in figs. 2, 3, and others.

The lettering on the pyramids of the other series in fig. 3, 1-2, 2-2, 4-2, indicates, by the second figure, that the planes are in the same vertical zone with the prismatic plane *i*-2, and by the first figure the relative lengths of the vertical axes.

In the twelve-sided prisms such ratios as *i*-$\frac{3}{2}$, *i*-$\frac{4}{3}$, *i*-$\frac{5}{4}$ occur. The fraction in any case expresses the ratio of the lateral axes for the particular planes. The double twelve-sided pyramids have the ratios 3-$\frac{3}{2}$ (fig. 2), 4-$\frac{4}{3}$, and others. Both in these forms and the twelve-sided prisms, the second figure in the lettering, expressing the ratio of the lateral axes, has necessarily a value between 1 and 2.

3. Hemihedral Forms.—Fig. 13 represents a crystal of apatite in which there are two sets of planes, *o* (=3-$\frac{3}{2}$) and *o'* (=4-$\frac{4}{3}$) which are hemihedral, only half of the full number of each *o* existing instead of all. This kind of hemihedrism consists in the suppression of an alternate half of the planes in each pyramid of the double twelve-sided pyramid (fig. 10), and in the suppressed planes of the upper pyramid being here directly over those suppressed in the lower pyramid. If the student will shade over half the planes alternately of the two pyramids, putting the shaded planes above directly over those below, he will understand the nature of the hemihedrism. In some hemihedral forms the suppressed planes of the upper pyramid alternate with those of the lower; but this kind occurs only in the rhombohedral section of the hexagonal system.

13.

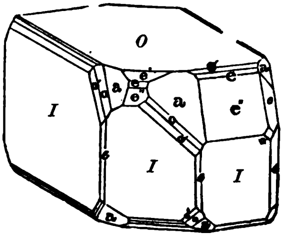


APATITE.

4. Cleavage.—Cleavage is usually basal, or parallel to a six sided pyramid. Sometimes there are traces of cleavage parallel to the faces of a six-sided pyramid.

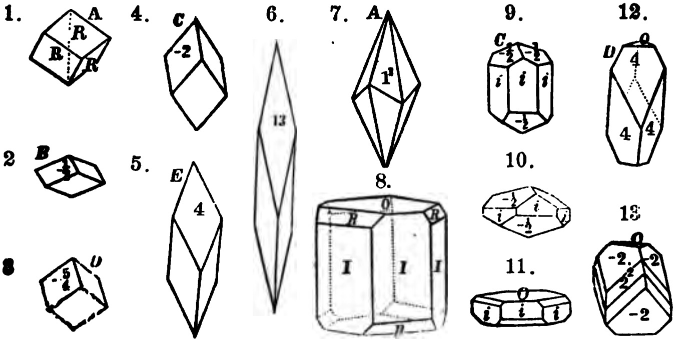
5. Irregularities of Crystals.—Distortions sometimes disguise greatly the real forms of hexagonal crystals by enlarging some planes at the expense of others. This is illustrated in fig. 14, representing the actual form presented by a crystal having the planes shown in fig. 13. Whenever in a prism the prismatic angle is exactly 120° or 150°, the form is almost always of the hexagonal system.

14.



2. RHOMBOHEDRAL SECTION.

1. Descriptions of Forms.—The following figures, 1 to 17, represent rhombohedral crystals, and all are of one mineral, calcite. They show that the planes of either end of the crystal are in threes, or multiples of threes, and that those above are alternate in position with those below. There is one exception



FIGURES OF CRYSTALS OF CALCITE.

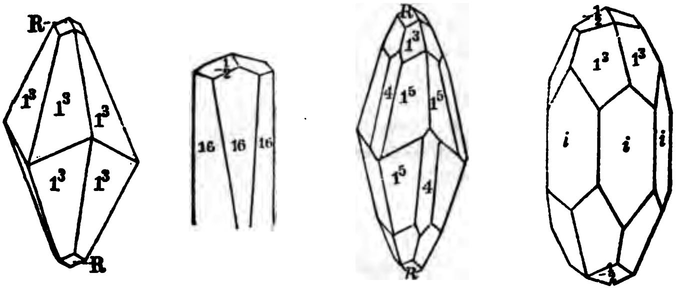
to this remark, that of the horizontal or basal plane *O*, in figs. 8, 11, 13. The simple rhombohedral forms include:

1. *Rhombohedrons*, figs. 1 to 6. These forms are included under six equal planes, like the cube, but these planes are

rhombic; and instead of having twelve rectangular edges, they have six obtuse edges and six acute.

2. *Scalenohedrons*, fig. 7. Scalenohedrons are really double six-sided pyramids; but the six equal faces of each extremity of the crystals are *scalene* triangles, and are arranged in three pairs; moreover the pairs above alternate with the pairs below; the edges in which the pairs above and below meet—that is the basal edges—make a zig-zag around the crystal.

14. 15. 16. 17.



FIGURES OF CRYSTALS OF CALCITE.

3. *Hexagonal prisms*, *I*, fig. 8. These are regular hexagonal prisms, having angles between their faces of 120°.

A rhombohedron has two of its solid angles made up of three equal plane angles. When in position the apex of one of these solid angles is directly over that of the other, as in figs. 1 to 6, and also in fig. 18, and the line connecting the apices of these angles (fig. 18) is called the vertical axis. In this position the rhombohedron has six terminal edges, three above and three below, and six lateral edges. As these lateral edges are symmetrically situated around the centre of the crystal, the three lines connecting the centres of opposite basal edges will cross at angles of 60°. These lines are the *lateral axes* of the

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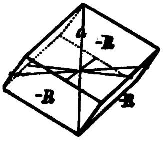

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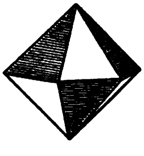

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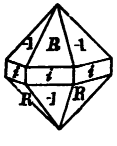

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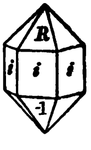
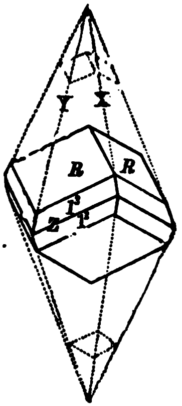


rhombohedron, and they are at right angles to the vertical axis. It is stated on page 45 that rhombohedral forms are, from a mathematical point of view, *hemihedral* under the hexagonal system. The rhombohedron, which may be considered a double three-sided pyramid, is hemihedral to the double six-sided pyramid. Fig. 19, representing the latter form, has its alternate faces shaded; suppressing the faces shaded the form would be that of fig. 18; and suppressing, instead of these, the faces not shaded, the form would be that of another rhombohedron, differing only in position. The two are distinguished as *plus* and *minus* rhombohedrons. They are combined in figs. 20, 21, forms of quartz. Rhombohedrons vary greatly in the length of the vertical axis with reference to the lateral. Figs. 1, 2, 3, and 18 represent crystals with the vertical axis short, and figs. 4, 5, 6 others with a long vertical axis. In the former the terminal edges are obtuse and the lateral acute, and the latter have the terminal edges acute and the lateral obtuse; the former are called obtuse rhombohedrons, and the latter acute.

The cube placed on one solid angle, with the diagonal between it and the opposite solid angle vertical, is, in fact, a rhombohedron intermediate between obtuse and acute rhombohedrons—the edges that are the terminal in this position, and those that are the lateral, being alike rectangular edges. Fig. 3 has nearly the form of a cube in this position.

The relation of one series of scalenohedrons to the rhombohedron is illustrated in fig. 22. This figure represents a rhombohedron with the lateral edges bevelled. These bevelling planes are those of a scalenohedron, and the outer lines of the same figure show the form of that scalenohedron which is obtained when the bevelment is continued to the obliteration of the rhombohedral planes. Fig. 14 represents this scalenohedron with the rhombohedral planes much reduced in size. Other scalenohedrons result when the terminal edges are bevelled, and still others from pairs of planes on the angles of a rhombohedron.

22.



The scalenohedron is hemihedral to the twelve-sided double pyramid (fig. 23).

In the hexagonal system the three vertical axial planes divide the space about the vertical axis into six sectors (fig. 12, p. 48).

The twelve-sided double pyramid has in each pyramid a pair of faces for each sector; that is, six pairs for each pyramid. If now the three alternate of these pairs, and those in the upper pyramid alternate with those of the lower (the shaded in fig. 23), were enlarged to the obliteration of the rest of the planes, the resulting form would be a scalenohedron—a solid with three pairs of planes to each pyramid instead of six. Such is the mathematical relation of the scalenohedron to the twelve-sided double pyramid. If the faces enlarged were those not shaded in fig. 23, another scalenohedron would be obtained which would be the *minus* scalenohedron, if the other were designated the *plus*.

23.

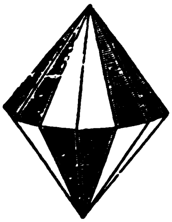


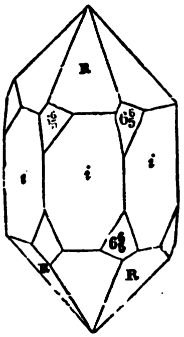
Fig. 8 shows the relations of a rhombohedron to a hexagonal prism. The planes *R* replace three of the terminal edges at each base of the prism, and those above alternate with those below. The extension of the planes *R* to the obliteration of those of the prismatic planes, *I*, and that of the basal plane *O*, would produce the rhombohedron of fig. 1. Figs. 9 and 10 represent the same prism, but with terminations made by the rhombohedron of fig. 2.

By comparing the above figures, and noting that the planes of similar forms are lettered alike, the combinations in the figures will be understood. Fig. 16 is a combination of the planes of the fundamental rhombohedron *R*, with those of another rhombohedron 4, and of two scalenohedrons 1^3 and 1^5. Fig. 17 contains the planes of the rhombohedron $-\frac{1}{2}$, with those of the scalenohedron 1^3, and those of the prism *i*. These figures, and figs. 14, 22, have the fundamental rhombohedron revolved 60° from the position in fig. 1, so that two planes *R* are in view above instead of the one in that figure.

2. Lettering of Figures.—Figs. 1 to 6, representing rhombohedrons of the species calcite, are lettered with numerals, excepting fig. 1. In fig. 1 the letter *R* stands for the numeral 1, and the numerals on the others represent the relative lengths of their vertical axes, the lateral being equal. In fig. 4 the vertical axis is twice that in fig. 1; in fig. 6 thirteen times; and in fig. 15 the planes lettered 16 are those of a rhombohedron whose vertical axis is sixteen times that of fig. 1. The rhombohedrons of figs. 1, 5, 6, and 15 are *plus* rhombohedrons; that is, they are in the same vertical series; while 2 and 3 are *minus* rhombohedrons, as explained above. The rhombohedron, when its vertical axis is reduced in length to zero, becomes the single basal plane lettered *O* in the series. If, on the contrary, the vertical axis of the rhombohedron is lengthened to infinity, the faces of the rhombohedron become those of a six-sided prism. This last will be seen from the relations of the planes *R* to *I* on fig. 8, and from the approximation to a prismatic form in the planes 16 of fig. 15. For an explanation of the lettering of other planes on rhombohedral crystals, reference must be made to the "Text-Book of Mineralogy."

3. Hemihedrism. Tetartohedrism.—Hemihedrism occurs among rhombohedral forms, similar to that in fig. 13, page 48, except that the suppressed planes of one pyramid are *alternate* with those of the other. One of these is represented in fig. 24. The planes 6-$\frac{6}{5}$ are six in number at each extremity, and are so situated that they give a spiral aspect to the crystal. If these planes were only three in number at each extremity, the alternate three of the six, the form would be tetartohedral to the double six-sided pyramid; that is, there would be one-fourth the number of planes that exist in the double twelve-sided pyramid, or 6 planes instead of 24. Such cases of hemihedrism and tetartohedrism are common in crystals of quartz, and when existing, the crystals are said to be *plagihedral*, from the Greek for *oblique* and *face*. In some crystals the spiral turns *to the right* and in others *to the left*, and the two kinds are distinguished as *right-handed* and *left-handed*. There are also tetartohedral forms in which one whole pyramid of a scalenohedron, or of a rhombohedron, is wanting. For example, in crystals of tourmaline rhombohedral planes, and sometimes scalenohedral, may occur at one extremity of the prism and be absent from the other. This dissimilarity in the two extremities of a crystal of tourmaline is connected with pyro-electric polarity in the mineral. Three-sided prisms, hemihedral to the hexagonal prism, are common in some rhombohedral species, as tourmaline.

24.



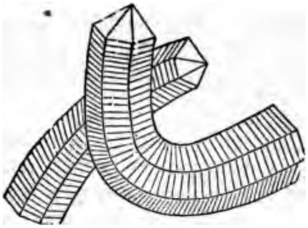
4. Cleavage.—Cleavage usually takes place parallel to the faces of a rhombohedron, as in calcite, corundum. Not unfrequently the rhombohedral cleavage is wanting, and there is highly perfect cleavage parallel to the basal plane, as in graphite, brucite.

25.

5. Irregularities of Crystals.—Distortions occur of the same nature with those under the other systems. Some examples are given under quartz. Some rhombohedral species, as dolomite, have the opposite faces convex or concave, as in fig. 25.

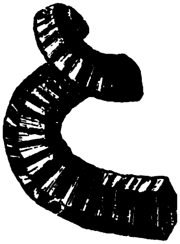
Occasional curved crystals occur, as in fig. 26, representing crystals of quartz, and fig. 27 of a crystal of chlorite. The feathery crystallizations on windows, called frost, are examples of curved forms under this system.

26.



QUARTZ.

27.



CHLORITE.

VII. DISTINGUISHING CHARACTERS OF THE SEVERAL SYSTEMS OF CRYSTALLIZATION.

1. Isometric System.—(1) There may be symmetrical groups of 4 and 8 similar planes about the extremities of each cubic axis; and of 3 or 6 similar planes about the extremities of each octahedral axis. (2) Simple holohedral forms may consist of 6 (cube), 8 (octahedron), 12 (dodecahedron), 24 (trapezohedron, trigonal trisoctahedron, and tetrahexahedron), and 48 (hexoctahedron) planes.

2. Dimetric System.—(1) Symmetrical groups of 4 and 8 similar planes occur about the extremities of the vertical axis only. (2) Prisms occur parallel only to the vertical axis; and these prisms are either square or eight-sided. (3) The simple holohedral forms may consist of 2 planes (the bases), of 4 planes (square prisms), of 8 planes (eight-sided prisms and square octahedrons), of 16 planes (double eight-sided pyramids).

3. Trimetric System.—(1) Symmetrical groups of 4 similar planes may occur about the extremities of either axis, but those of one axis belong equally to the others. (2) The prisms are rhombic prisms only, and these may occur parallel to either axis, the horizontal as well as the vertical. (3) Simple holo-

hedral forms may consist of 2 planes (the bases, and each pair of diametral planes), of 4 planes (rhombic prisms in the three axial directions), and of 8 planes (the rhombic octahedrons). (4) The forms may be divided into equal halves, symmetrical in planes, along each of the diametral sections.

4. MONOCLINIC SYSTEM. — (1) No symmetrical groups of similar planes ever occur around the extremities of either axis. (2) The prisms are rhombic prisms, and these can occur parallel only to the vertical axis and the clinodiagonal. (3) The planes occurring in vertical sections above and below the basal section, either in front or behind, are all unlike in inclination to that section, excepting the prismatic planes in the orthodiagonal zone; in other words, true prisms occur in no vertical section excepting the orthodiagonal. (4) Simple forms consist of 2 planes (the bases, the diametral planes, and hemiorthodomes), of 4 planes (rhombic prisms in two directions and hemioctahedrons). (4) The forms may be divided into equal and similar halves only along the clinodiagonal section. No interfacial angle of 90° occurs except between the planes of the clinodiagonal zone and the clinopinacoid.

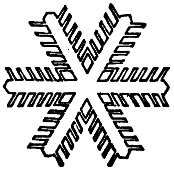
5. TRICLINIC SYSTEM. — In triclinic crystals there are no groups of similar planes which include more than 2 planes, and hence the simple forms consist of 2 planes only. The forms are not divisible into halves having symmetrical planes. There are no interfacial angles of 90°.

6. HEXAGONAL SYSTEM.—Symmetrical groups of 3, 6, and 12 similar planes may occur about the extremities of the vertical axis. (2) Prisms occur parallel to the vertical axis, and are either six or twelve-sided (3 in a hemihedral form) and equilateral. (3) Simple holohedral forms may consist of 2 planes (the basal), of 6 planes (hexagonal prism), of 12 planes (twelve-sided prisms and double six-sided pyramids), of 24 planes (double twelve-sided pyramids). Simple rhombohedral forms may consist of 2 planes (the basal), of 6 planes (rhombohedrons), and of 12 planes (scalenohedrons).

2. TWIN, OR COMPOUND CRYSTALS.

Compound crystals consist of two or more single crystals, united usually parallel to an axial or diagonal section. A few are represented in the following figures. Fig. 1 represents a crystal of snow of not unfrequent occurrence. As is evident to the eye, it consists either of six crystals meeting in a point, or of three crystals crossing one another; and besides, there are numerous minute crystals regularly arranged along the rays. Fig. 2 represents a cross (cruciform) crystal of staurolite, which is similarly compound, but made up of two intersecting crystals. Fig. 3 is a compound crystal of gypsum, and fig. 4 one of spinel. These will be understood from the following figures.

1.



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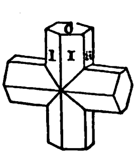

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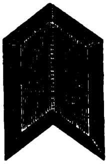

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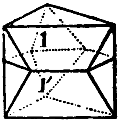

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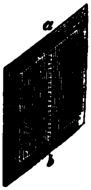

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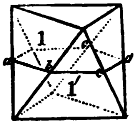


Fig. 5 is a *simple* crystal of gypsum; if it be bisected along *a b*, and the right half be inverted and applied to the other, it will form fig. 3, which is therefore a twin crystal in which one half has a reverse position from the other. Fig. 6 is a simple octahedron; if it be bisected along the plane *a b c d e*, and the upper half, after being revolved half way around, be then united to the lower, it will have the form in fig. 4. Both of these, therefore, are similar twins, in which one of the two component parts is reversed in position.

Crystals like figs. 3 and 4 have proceeded from a compound nucleus in which one of the two molecules was reversed; and those like fig. 1, from a nucleus of three (or six) molecules. Compound crystals of the kinds above described, thus differ from simple crystals in having been formed from a nucleus of two or more united molecules, instead of from a simple nucleus.

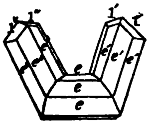
Compound crystals are generally distinguished by their re-entering angles, and often also by the meeting of striæ at an angle along a line on a surface of a crystal, the line indicating the plane of junction of the two crystals.

Compound crystals are called *twolings*, *threelings*, *fourlings*, according as they consist of two, three, or four united crystals.

Fig. 1 represents a threeling, and 2, 3, and 4, twolings. In 3 and 4 the combined crystals are simply in contact along the plane of junction; in 2 they cross one another; the former are called *contact-twins* and the latter *penetration-twins.*

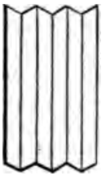
Besides the above, there are also geniculated crystals, as in the annexed figure of a crystal of rutile. The bending has here taken place at equal distances from the centre of the crystal, and it must therefore have been subsequent in time to the commencement of the crystal. The prism began from a simple molecule; but after attaining a certain length an abrupt change of direction took place. The angle of geniculation is constant in the same mineral species, for the same reason that the interfacial angles of planes are fixed; and it is such that a cross section directly through the geniculation is parallel to the position of a common secondary plane. In the figure given the plane of geniculation is parallel to one of the terminal edges. In rutile the geniculated crystals sometimes repeat the bendings at each end until the extremities meet to form a wheel-like twin.

7.



In some species, as albite, the reversion of position on which this kind of twin depends, takes place at so short intervals that the crystal consists of parallel plates, each plate often less than a twentieth of an inch in thickness. A section of such a crystal, made transverse to the plate, is given in fig. 8; without the twinning the section would have been as in fig. 9. The plates, as the figure shows, make with one another at their edges a re-entering angle (in albite an angle of 172° 48′), and hence a plane of the albite crystal at right angles to the twinning direction, is covered with a series of ridges and depressions which are so minute as to be only fine striations, sometimes requiring a magnifying power to distinguish. Such striations in albite are therefore an indication of the compound structure.

8.



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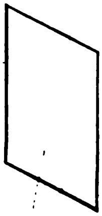
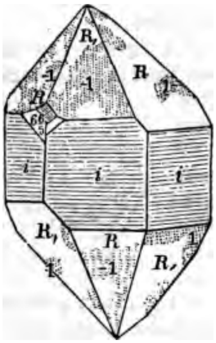


This kind of twinning is owing to successive changes of polarity in the molecules as the enlargement of the crystal went forward. It occurs in all the triclinic feldspars, and is a means of distinguishing them from orthoclase.

In some twin crystals the two component parts of the crystal are not united by an even plane, but run into one another with great irregularity. Cases of this kind occur in the species of quartz in twins made up of the forms *R* and $-R$ (or -1). In fig. 10 the shaded parts of the pyramidal planes are of the form -1, and the non-shaded parts of *R*. Each of the faces is made up partly of *R* and partly of -1. The limits of the two are easily seen on holding the crystal up to the light, since the -1 portion is less well polished than the other. In this crystal, as in other crystals of quartz, the striations of planes *i* are owing to oscillations between pyramidal and prismatic planes while the formation of the latter was in progress.

10.



3. CRYSTALLINE AGGREGATES.

The crystalline aggregates here included are the simple, not the mixed; that is, they are those consisting of crystalline individuals of a single species.

The crystalline individuals may be (1) distinct crystals; (2) fibres or columns; (3) scales or lamellæ; or (4) grains, either cleavable or not so.

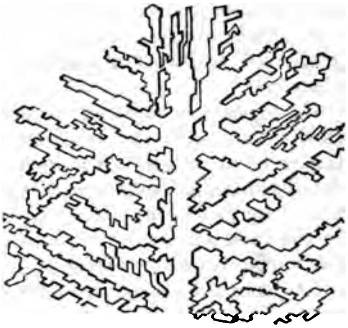
1. *Consisting of distinct crystals.*—The *distinct crystal* may be either long or short *prismatic*, stout or slender to *acicular* (needle-like), and *capillary* (hair-like); or they may have any other forms of crystals. They may be aggregated (*a*) in lines; (*b*) promiscuously with open spaces; (*c*) over broad surfaces; (*d*) about centres. The various kinds of aggregates thus made are:

a. Filiform.—Thread-like lines of crystals, the crystals often not well defined.

b. Dendritic.—Arborescent slender spreading branches, somewhat plant-like, made up of more or less distinct crystals, as in the frost on windows, and in arborescent forms of native copper, silver, gold, etc.

Fig. 11 represents, much magnified an arborescent form of magnetite occurring in mica at Pennsbury, in Pennsylvania. Arborescent delineations over surfaces of rock are usually called *dendrites.* They have been formed by crystallization from a solution of mineral matter which has entered by some crack and spread between the layers of the rock. They are often black, and consist of oxide of manganese; others, of a brownish color, are made of limonite; others, of a reddish black or black color, of hematite. Moss-like forms also occur, as in moss agate.

11.



c. Reticulated. — Slender prismatic crystals promiscuously crossing, with open spacings.

d. Divergent.—Free crystals radiating from a central point.

e. Drusy.—A surface is *drusy* when made up of the extremities of small crystals.

2. Consisting of *columnar individuals.*

a. Columnar, when the columnar individuals are stout.

b. Fibrous, when they are slender.

c. Parallel fibres, when the fibres are parallel.

d. Radiated, when the columns or fibres radiate from centres.

e. Stellated, when the radiations from a centre are equal around, so as to make star-like or circularly-radiated groups.

f. Globular, when the radiated individuals make globular or hemispherical forms, as in wavellite.

g. Botryoidal, when the globular forms are in groups, a little like a bunch of grapes. The word is from the Greek for a bunch of grapes.

h. Mammillary, having a surface made up of low and broad prominences. The term is from the Latin *mammilla*, a *little teat.*

i. Coralloidal, when in open-spaced groupings of slender stems, looking like a delicate coral. A result of successive additions at the extremity of a prominence, lengthening it into cylinders, the stems generally having a faintly radiated structure.

Specimens of all these varieties of columnar structure, excepting the last, often have a *drusy* surface, the fibres or columns ending in projecting crystals.

3. *Consisting of scales or lamellæ.*

a. Plumose, having a divergent arrangement of scales, as seen on a surface of fracture; *e. g.*, plumose mica.

b. Lamellar, tabular, consisting of flat lamellar crystalline individuals, superimposed and adhering.

c. Micaceous, having a thin fissile character, due to the aggregation of scales of a mineral which, like mica, has eminent cleavage.

d. Septate, consisting of openly-spaced intersecting tabular individuals; also divided into polygonal portions by reticulating veins or plates. A *septarium* is a concretion, usually flattened spheroidal in shape, the solid interior of which is intersected by partitions; these partitions are the fillings of cracks in the interior that were due to contraction on drying. When the surface of such septate concretions has been worn off, they often have the appearance of a turtle's back, and are sometimes taken for petrified turtles.

4. *Consisting of grains. Granular structure.* A massive mineral may be *coarsely granular* or *finely granular*, as in varieties of marble, granular quartz, etc. It is termed *saccharoidal* when evenly granular, like loaf sugar. It may also be *cryptocrystalline*, that is, having no distinct grains that can be detected by the unaided eye, as in flint. The term cryptocrystalline is from the Greek for *concealed crystalline. Aphanitic*, from the Greek for *invisible*, has the same signification. The term *ceroid* is applied when this texture is connected with a waxy lustre, as in some common opal.

Under this section occur also *globular, botryoidal*, and *mammillary* forms, as a result of concretionary action in which no distinct columnar interior structure is produced. They are called *pisolitic* when in masses consisting of grains as large as peas (from the Latin *pisum, a pea*), and *oölitic* when the grains are not larger than the roe of a fish, from the Greek for *egg*.

5. *Forms depending on mode of deposition.*—Besides the above, there are the following varieties which have come from mode of deposition:

a. Stalactitic, having the form of a cylinder, or cone, hanging from the roofs of cavities or caves. The term stalactite is usually restricted to the cylinders of carbonate of calcium hanging from the roofs of caverns; but other minerals are said to have a stalactitic form when resembling these in their general shape and origin. Chalcedony and brown iron ore are often stalactitic. Interiorly the structure may be either granular, radiately fibrous, or concentric.

b. Concentric.—When consisting of lamellæ, lapping one over another around a centre, a result of successive concretionary aggregations, as in many *concretionary* forms, most *pisolite*, part of *oölite*, some *stalactites*, etc.

c. Stratified, consisting of layers, as a result of deposition: *e. g.*, some travertine, or tufa.

d. Banded; color-stratified. Like stratified in origin, but the layers usually indicated only by variations in color; the banding is shown in a transverse section: *e. g.*, agate, much stalagmite, riband jasper.

e. Geodes.—When a cavity has been lined by the deposition of mineral matter, but not wholly filled, the enclosing mineral is called a geode. The mineral is often banded, owing to the successive depositions of the material, and frequently has its inner surface set with crystals. Agates are often slices or fragments of geodes.

6. *Forms derived from the crystals of other minerals. Pseudomorphs.*—Crystalline aggregates, especially the granular, sometimes have forms derived from the crystals of other minerals either

(1) Because a result of cotemporaneous removal and substitution; or

(2) Because a result of the alteration of such crystals; or

(3) Because filling spaces that had been left unoccupied in consequence of previous removal.

For example. Crystals occur having the forms of calcite (calcium carbonate, or "carbonate of lime"), but consisting of quartz or silica. They were made from calcite crystals by the action of some solution containing silica, the solution dissolving away the calcite and depositing at the same time silica or quartz. Specimens occur showing all stages in the change from the earliest in which the calcite is thinly coated with quartz, to the last, in which it is all quartz. Such crystals are pseudomorphs of quartz after calcite. Siliceous fossil shells and corals are similar pseudomorphs after calcite, since shells and corals consist chiefly of calcite. Other quartz pseudomorphs have the form of fluorite, barite, etc.

Again, the forms of calcite occur with the constitution of limonite, a hydrous iron oxide. In such a case the iron oxide was in the solution that corroded and dissolved away the calcite.

Again, the forms of calcite occur with the constitution of serpentine, a hydrous magnesium silicate; and in this case the ingredients of the serpentine silicate were present when the calcite was dissolved away by the corrosive solvent, and took its place as the calcite particles were removed.

In all the above cases the pseudomorphs were made by simple removal and cotemporaneous *substitution.*

Again, crystals of the form of chrysolite, a magnesium silicate, occur, altered to serpentine, a *hydrous* magnesium silicate. Here the pseudomorph was made by a process of *alteration*, part of the ingredients remaining, and only water added.

Again, crystals of siderite (spathic iron or iron carbonate) occur changed to limonite, a hydrous iron oxide. Here there was an oxidation of the iron of the carbonate, and the addition of water. This is another example of pseudomorphs by *alteration.* Similarly orthoclase changes to kaolin, and kaolin has the form at times of orthoclase crystals.

Again, crystals of the form of those of common salt occur consisting of clay or of calcite, which were made by deposition in a cavity left by the dissolving away of an imbedded crystal of salt. These are pseudomorphs by *deposition.*

Again, crystals of aragonite, *prismatic* calcium carbonate, occur consisting of calcite or *rhombohedral* calcium carbonate; and here there is a change in crystallization without any change of chemical composition.

7. *Fracture.*—Kinds of fracture in these crystalline aggregates depend on the size and form of the particles, their cohesion, and to some extent their having cleavage or not.

Among granular varieties, the influence of cleavage is in all cases very small, and in the finest almost or quite nothing. The term *hackly* is used for the surface of fracture of a metal, when the grains are coarse, hard, and cleavable, so as to be sharp and jagged to the touch; *even*, for any surface of fracture when it is nearly or quite flat, or not at all conchoidal; *conchoidal*, when the mineral, owing to its extremely fine or cryptocrystalline texture and hardness, breaks with shallow concavities and convexities over the surface, as in the case of flint. The word conchoidal is from the Latin *concha*, a shell. These kinds of fracture are not of much importance in mineralogy, since they distinguish varieties of minerals only, and not species.

2. PHYSICAL PROPERTIES OF MINERALS.

THE physical properties referred to in the description and determination of minerals are here treated under the following heads: (1) Hardness; (2) Tenacity; (3) Specific Gravity; (4) Refraction, Polarization; (5) Diaphaneity, Color, Lustre; (6) Electricity and Magnetism; (7) Taste and Odor.

1. HARDNESS.

The comparative hardness of minerals is easily ascertained, and should be the first character attended to by the student in examining a specimen. It is only necessary to draw a file across the specimen, or to make trials of scratching one with another. As standards of comparison the following minerals have been selected, increasing gradually in hardness from *talc*, which is very soft and easily cut with a knife, to the *diamond*. This table, called the *scale of hardness*, is as follows:

1, *talc*, common foliated variety; 2, *rock salt*; 3, *calcite*, transparent variety; 4, *fluorite*, crystallized variety; 5, *apatite*, transparent crystal; 6, *orthoclase*, cleavable variety; 7, *quartz*, transparent variety; 8, *topaz*, transparent crystal; 9, *sapphire*, cleavable variety; 10, *diamond*.

If, on drawing a file across a mineral, it is impressed as easily as *fluorite*, the hardness is said to be 4; if as easily as *orthoclase*, the hardness is said to be 6; if more easily than orthoclase, but with more difficulty than apatite, its hardness is described as 5½ or 5·5.

The file should be run across the mineral three or four times, and care should be taken to make the trial on angles equally blunt, and on parts of the specimen not altered by exposure. Trials should also be made by scratching the specimen under examination with the minerals in the above scale, since sometimes, owing to a loose aggregation of particles, the file wears down the specimen rapidly, although the particles are very hard.

In crystals the hardness is sometimes appreciably different in degree in the direction of different axes. In crystals of mica the hardness is less on the basal plane of the prism, that is, on the cleavage surface, than it is on the sides of the prism. On the contrary, the termination of a crystal of cyanite is harder than the lateral planes The degree of hardness in different directions may be obtained with great accuracy by means of an instrument called a *sclerometer.*

2. TENACITY.

The following rather indefinite terms are used with reference to the qualities of tenacity, malleability, and flexibility in minerals:

1. *Brittle.*—When a mineral breaks easily, or when parts of the mineral separate in powder on attempting to cut it.

2. *Malleable.*—When slices may be cut off, and these slices will flatten out under the hammer, as in native gold, silver, copper.

3. *Sectile.*—When thin slices may be cut off with a knife. All malleable minerals are sectile. Argentite and cerargyrite are examples of sectile ores of silver. The former cuts nearly like lead and the latter nearly like wax, which it resembles. Minerals are *imperfectly sectile* when the pieces cut off pulverize easily under a hammer, or barely hold together, as selenite.

4. *Flexible.*—When the mineral will bend, and remain bent after the bending force is removed. Example, talc.

5. *Elastic.*—When, after being bent, it will spring back to its original position. Example, mica.

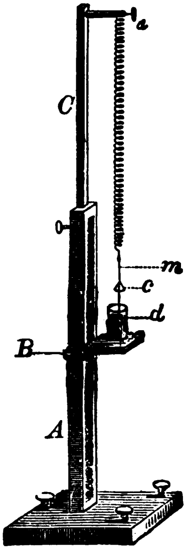
A liquid is said to be *viscous* when on pouring it the drops lengthen and appear ropy. Example, petroleum.

3. SPECIFIC GRAVITY.

The specific gravity of a mineral is its weight compared with that of some substance taken as a standard. For solids and liquids *distilled water*, at 60° F., is the standard ordinarily used; and if a mineral weighs twice as much as water, its specific gravity is 2; if three times it is three. It is then necessary to compare the weight of the mineral with the weight of an equal bulk of water. The process is as follows:

First weigh a fragment of the mineral in the ordinary way, with a delicate balance; next suspend the mineral by a hair, or fibre of silk, or a fine platinum wire, to one of the scales, immerse it thus suspended in a glass of distilled water (keeping the scales clear of the water) and weigh it again; subtract the *second* weight from the *first*, to ascertain the loss by immersion, and divide the *first* by the difference obtained; the result is the specific gravity. The loss by immersion is equal to the weight of an equal volume of water. The trial should be made on a small fragment; two to five grains are best. The specimen should be free from impurities and from pores or air-bubbles. For exact results the temperature of the water should be noted, and an allowance be made for any variation from the height of thirty inches in the barometer. The observation is usually made with the water at a temperature of 60° F.; 39°·5 F., the temperature of the maximum density of water, is preferable.

The accompanying figure represents the spiral balance of Jolly, by which the weight is measured by the torsion of a spiral brass wire. On the side of the upright (*A*) which faces the spiral wire, there is a graduated mirror, and the readings which give the weight of the mineral in and out of water are made by means of an index (at *m*) connected with the spiral wire; and its exact height, with reference to the graduation, is obtained by noting the coincidence between it and its image as reflected by the graduated mirror. *c* and *d* are the pans in which the piece of mineral is placed, first in *c*, the one out of the water, and then in *d*, that in the water.



Another process, and one available for *porous* as well as compact minerals, is performed with a light glass bottle, capable of holding exactly a thousand grains (or any known weight) of distilled water. The specimen should be reduced to a coarse powder. Pour out a few drops of water from the bottle and weigh it; then add the powdered mineral till the water is again to the brim, and reweigh it; the difference in the two weights, divided by the loss of water poured out, is the specific gravity sought. The weight of the glass bottle itself is here supposed to be balanced by an equivalent weight in the other scale.

4. REFRACTION AND POLARIZATION.

Minerals differ widely in their refracting and polarizing properties, and hence these properties are a convenient means of distinguishing species. The explanations of the subject, and the methods of careful experimenting, will be found in treatises on optics, and also at considerable length, and with minute directions as to the use of instruments, in the Text-Book of Mineralogy. Only a few of the simpler facts required for the ordinary purposes of the mineralogist are here mentioned.

The character of the refraction varies according to the system of crystallization.

A. In isometric crystals there is simple refraction alike in all directions, and no polarization.

B. In dimetric and hexagonal crystals the vertical axis, or axis of symmetry, is the direction of the *optic axis;* in all directions except this a transmitted ray of light is doubly refracted. Such crystals are optically *uniaxial.*

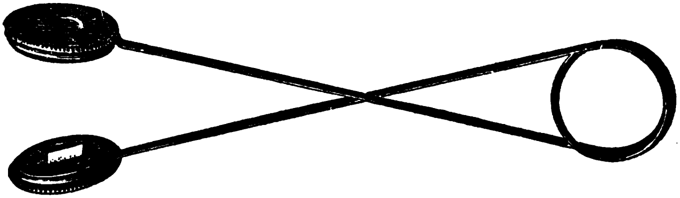
C. In trimetric, monoclinic, and triclinic crystals, which have the three axes unequal, there are *two* directions of no double-refraction. Such crystals are optically *biaxial.*

1. *Isometric System.*—In the isometric system there is no reference whatever in the refraction to crystalline structure, and in this respect substances thus crystallizing are like water. There is only simple refraction. The index of refraction is obtained by dividing the sine of the angle of incidence of a ray of light by the sine of its angle of refraction. Thus if a ray of light strike the surface of a transparent plate of the mineral at an angle of 40° from the perpendicular, and then passes through the plate at an angle of 30° from the perpendicular, owing to the refraction, the sine of 40° divided by the sine of 30° will be the index of refraction. Now the index of refraction of air being made the unit, that of water is 1·335; of fluorite, 1·434; of rock salt, 1·557; of spinel, 1·764; of garnet, 1·815; of blende, 2·260; of diamond, 2·439.

2. *Crystals Uniaxial in Polarization.*—A transparent cleavage plate from a crystal of calcite shows what is called *double refraction.* Placed over a line drawn on any surface, two parallel lines are seen, one produced by the *ordinary* ray, and the other by the *extraordinary* ray. Both rays are polarized, and in planes at right angles to each other. Prisms, called Nicol prisms, made from transparent calcite (Iceland Spar), are employed for obtaining polarized light. Transparent

plates of tourmaline, cut from a crystal parallel to the vertical axis, also are used for this purpose. Another method of obtaining it is by reflection—light, when reflected at a certain angle from a polished surface, being polarized; the angle of reflection differs for different substances.

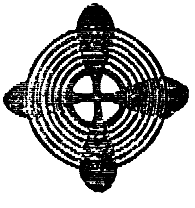
1.



The above figure represents a simple *polariscope* made with two tourmaline plates, which is convenient for many ordinary observations. The best instruments for the purpose are made with Nicol prisms, and are adapted to microscopic work. The prisms, placed within the tube of the instrument, one of them below the stage, are arranged so as to admit of revolution; and the stage also has a graduated circle and revolves. The compound microscope also is often converted into a polariscope by Nicol prisms arranged for this purpose.

When a crystal with one axis of polarization, as, for example, calcite, is examined by means of a ray of polarized light passed in the direction of the vertical axis, concentric circular rings are seen, having the colors of the spectrum intersected by either a black or a white cross, as in figs. 1, 2. To make the observation it is necessary that the calcite crystal should have its extremities polished at right angles to the vertical axis. If a tourmaline plate be placed against or near one of its polished

2.



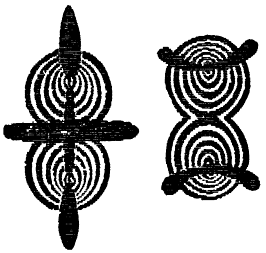
3.

faces, and a similar tourmaline plate in front of the opposite face, the colored rings will be seen on looking through; and by revolving one of the tourmaline plates a change will be observed at each 90° of revolution, in the colors of the rings, and in the variations in appearance of the cross from black to white, and the reverse. The fact in any case that the rings of color are perfect circles, and the black cross a symmetrical one, is proof that the crystal is either of the *dimetric* or *hexagonal* system. But sometimes very exact observation is necessary to determine the truth.

3. *Crystals Biaxial in Polarization.*—Biaxial crystals are those having two optic axes, and the angle between them is called the *axial angle.*

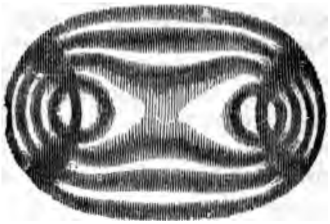
When a section of such a crystal, at right angles to the line bisecting the acute axial angle, is viewed in converging polarized light, the two axes are seen with a series of elliptical colored rings surrounding each. If the section is so placed that the line joining the axes coincides with the vibration-plane of either Nicol prism, or tourmaline plate, an unsymmetrical black cross is also seen, as in fig. 4; if it makes an angle of 45° with this, two curved black bars are observed, as in fig. 5. In either case the colors are reversed, and the black changed to white as one of the Nicols is revolved. Fig. 6 shows the axial figure for phlogopite (in the second position mentioned above) where the axial angle is very small. The rings are less numerous and farther apart the thinner the section that is employed in making the observations.

4. 5.



GLAUBER SALT.

6.



PHLOGOPITE, ANTWERP, N. Y.

In muscovite (common mica) the angle between the axes is 50° to 70°, and, if the tourmaline tongs are employed, the two series of rings are visible only when viewed in directions very oblique to one another.

4. *Circular Polarization in Uniaxial Crystals.*—It is stated on page 53 that quartz crystals have often a left-handed and a right-handed arrangement of planes. This is connected with a right-handed and left-handed molecular structure in crystals of this species. When a plate cut at right angles to the axis is examined by the polarized light, instead of presenting a black cross, the centre of the rings appears brightly colored, and if the polarizer is revolved, this color changes from blue to yellow, then red, right-handed crystals requiring revolution to the right and left-handed to the left for this succession. This property seems to distinguish the smallest grains of quartz, and may be easily observed in a good polariscope.

5. *Anomalies in Polarization.*—There are some isometric crystals which have the property of polarization. Boracite is one example; and it is explained by the presence of another mineral in minute particles, distributed regularly through the crystals. Perofskite is another case; and it has suggested a doubt as to its being isometric. Octahedrons of alum sometimes have polarization, and it has been shown to be due to the crystals being made up of thin plates—light, when transmitted through a pile of such plates, becoming polarized. Diamonds are sometimes uniaxial.

7.

Analcite was long since described by Sir David Brewster as an example of polarization under the isometric system. Its trapezohedrons exhibit a symmetrical arrangement of lines of prismatic colors and alternating dark lines with cross-bands, as imperfectly shown in the annexed figure. Trapezohedrons of leucite are somewhat similar in their polarizing character. The effect in both species is connected with twinning; but, besides, according to recent observers, the crystallization is *dimetric*. One writer makes crystals of analcite to be *trimetric* twins, analogous those of phillipsite. Twinning in crystals is a very common source of irregularities. A regular twinning of laminæ of biaxial crystals around a centre may give a uniaxial character to the twin. Apophyllite is a *dimetric* species, showing peculiarities in its colors arising from the different action of the mineral in light of different colors.

5. DIAPHANEITY, LUSTRE, COLOR.

1. DIAPHANEITY.

Diaphaneity is the property which many objects possess of *transmitting* light; or, in other words, of permitting more or less light to pass through them. This property is often called *transparency*, but transparency is properly one of the degrees of diaphaneity. The following terms are used to express the different degrees of this property:

Transparent—a mineral is said to be transparent when the outlines of objects, viewed through it, are distinct. Example, glass, crystals of quartz.

Subtransparent, or *semitransparent*—when objects are seen but their outlines are indistinct.

Translucent—when light is transmitted, but objects are not seen. Loaf sugar is a good example; also Carrara marble.

Subtranslucent—when merely the edges transmit light faintly.

When no light is transmitted the mineral is described as *opaque*.

2. LUSTRE.

The lustre of minerals depends on the nature of their surfaces, which causes more or less light to be reflected. There are different degrees of *intensity of lustre*, and also different *kinds of lustre*.

a. The *kinds of lustre* are six, and are named from some familiar object or class of objects.

1. *Metallic*—the usual lustre of metals. Imperfect metallic lustre is expressed by the term *submetallic*.

2. *Vitreous*—the lustre of broken glass. An imperfect vitreous lustre is termed *subvitreous*. Both the vitreous and subvitreous lustres are common. Quartz possesses the former in an eminent degree; calcareous spar often the latter. This kind of lustre may be exhibited by minerals of any color.

3. *Resinous*—lustre of the yellow resins. Example, some opal, zinc blende.

4. *Pearly*—like pearl. Example, talc, native magnesia, stilbite, etc. When united with submetallic lustre the term *metallic-pearly* is applied.

5. *Silky*—like silk; it is the result of a fibrous structure.

Example, fibrous calcite, fibrous gypsum, and many fibrous minerals, more especially those which in other forms have a pearly lustre.

6. *Adamantine*—the lustre of the diamond. When submetallic, it is termed *metallic adamantine.* Example, some varieties of white lead ore or cerussite.

b. The *degrees of intensity* are denominated as follows:

1. *Splendent*—when the surface reflects light with great brilliancy and gives well-defined images. Example, Elba hematite, tin ore, some specimens of quartz and pyrite.

2. *Shining*—when an image is produced, but not a well-defined image. Example, calcite, celestite.

3. *Glistening*—when there is a general reflection from the surface, but no image. Example, talc.

4. *Glimmering*—when the reflection is very imperfect, and apparently from points scattered over the surface. Example, flint, chalcedony.

A mineral is said to be *dull* when there is a total absence of lustre. Example, chalk.

3. Color.

1. *Kinds of Color.*—In distinguishing minerals, both the external color and the color of a surface that has been rubbed or scratched, are observed. The latter is called the *streak*, and the powder abraded, the *streak-powder.*

The colors are either *metallic* or *unmetallic.*

The metallic are named after some familiar metal, as copper-red, bronze-yellow, brass-yellow, gold-yellow, steel-gray, lead-gray, iron-gray.

The unmetallic colors used in characterizing minerals are various shades of *white, gray, black, blue, green, yellow, red* and *brown.*

There are thus snow-white, reddish-white, greenish-white, milk-white, yellowish-white.

Bluish-gray, smoke-gray, greenish-gray, pearl-gray, ash-gray.

Velvet-black, greenish-black, bluish-black, grayish-black.

Azure-blue, violet-blue, sky-blue, indigo-blue.

Emerald-green, olive-green, oil-green, grass-green, apple-green, blackish-green, pistachio-green (yellowish).

Sulphur-yellow, straw-yellow, wax-yellow, ochre-yellow, honey-yellow, orange-yellow.

Scarlet-red, blood-red, flesh-red, brick-red, hyacinth-red, rose-red, cherry-red.

Hair-brown, reddish-brown, chestnut-brown, yellowish-brown, pinchbeck-brown, wood-brown.

A *play of colors*—this expression is used when several prismatic colors appear in rapid succession on turning the mineral. The diamond is a striking example ; also precious opal.

Change of colors—when the colors change slowly on turning in different positions, as in labradorite.

Opalescence—when there is a milky or pearly reflection from the interior of a specimen, as in some opals, and in cat's eye.

Iridescence—when prismatic colors are seen within a crystal, it is the effect of fracture, and is common in quartz.

Tarnish—when the surface colors differ from the interior; it is the result of exposure. The tarnish is described as *irised* when it has the hues of the rainbow.

2. *Dichroism*, *Trichroism*.—Some crystals, under each of the systems excepting the isometric, have the property of presenting different colors by transmitted light in different directions. The property is called *dichroism* when these colors are seen in two directions, and *trichroism* (or *pleochroism*) if seen in three directions. The colors are always the same in the direction of equal axes and often unlike in the direction of unequal axes. As dimetric and hexagonal crystals have the lateral axes equal they can present different colors only in two directions, the vertical and lateral; while all crystals that are optically biaxial may be trichroic.

The mineral iolite is a noted example, and received the name *dichroite* on account of this property. Transparent colored crystals of tourmaline, topaz, epidote, mica, diaspore, and many other species exhibit it. Tourmaline crystals, when transparent or translucent transverse to the prism, are opaque in the direction of the vertical axis; and so also are thick crystals of mica. Colored varieties of hornblende are dichroic, while those of the related mineral, pyroxene, are not so.

This quality is best observed by means of polarized light. On examining a mineral with a tourmaline plate, or Nicol prism, the two colors in a dichroic mineral are successively seen as the tourmaline or Nicol is revolved; and if there is no dichroism there is no change of color. A small instrument, containing a prism of calcite, has been constructed for showing the dichroism, called the *dichroscope*. On looking through it at a dichroic crystal, the aperture against the crystal appears double, owing to the double refraction of the calcite, one image being made by the ordinary ray and the other by the extraordinary ray; and the two colors are seen side by side, at intervals of 90° in the revolution of the mineral.

For opaque minerals it is necessary to make a thin transparent section of the mineral and examine it with a polariscope, or with a microscope arranged to act as one by the addition of one Nicol prism. The opaque hornblende of rocks is thus distinguished from pyroxene, and so in other cases.

3. *Asterism.*—Some crystals, especially the hexagonal, when viewed in the direction of the vertical axis, present peculiar reflections in six radial directions. This arises either from peculiarities of texture along the axial portions, or from some impurities. A remarkable example of it is that of the *asteriated* sapphire, and the quality adds much to its value as a gem. The six rays are sometimes alternately shorter, indicating the rhombohedral character of the crystal.

4. *Phosphorescence.*—Several minerals give out light either by friction or when gently heated. This property of emitting light is called *phosphorescence.*

Two pieces of white sugar struck against one another give a feeble light, which may be seen in a dark place. The same effect is obtained on striking together fragments of quartz, and even the passing of a feather rapidly over some specimens of zinc blende is sufficient to elicit light.

Fluorite is the most convenient mineral for showing phosphorescence by heat. On powdering it, and throwing it on a plate of metal heated nearly to redness, the whole takes on a bright glow. In some varieties the light is emerald green; in others, purple, rose, or orange. A massive fluor, from Huntington, Connecticut, shows beautifully the emerald green phosphorescence.

Some kinds of white marble, treated in the same way, give out a bright yellow light.

After being heated for a while the mineral loses its phosphorescence; but a few electric shocks will, in many cases, to some degree restore it again.

6. ELECTRICITY, AND MAGNETISM.

Electricity.—Many minerals become electrified on being rubbed, so that they will attract cotton and other light substances; and when electrified some exhibit positive and others negative electricity, when brought near a delicately suspended magnetic needle. The diamond, whether polished or not, always exhibits positive electricity, while other gems become negatively electric in the rough state, and positively only in the polished state. Some minerals, thus electrified, retain the power of electric attraction for many hours, as topaz, while others lose it in a few minutes.

Many minerals become electric when heated, and such species are said to be *pyro-electric*, from the Greek *pui*, fire, and electric.

A prism of tourmaline, on being heated, becomes polar; one extremity will be attracted, the other repelled, by a pole of a strong magnet. The prisms of tourmaline have different secondary planes at the two extremities.

Several other minerals have this peculiar electric property, especially boracite and topaz, which, like tourmaline, are *hemihedral* in their modifications. Boracite crystallizes in cubes, with only the alternate solid angles similarly replaced (figs. 39, 40, page 25). Each solid angle, on heating the crystals, becomes an electric pole; the angles diagonally opposite are differently modified and have opposite polarity. Pyroelectricity has been observed also in crystals that are not hemihedral, and in many mineral species. In some cases the number of poles is more than two. In prehnite crystals a large series occur distributed over the surface.

MAGNETISM.—The name *Lodestone* is given to those specimens of an ore of iron, called magnetite which have the power of attraction like a magnet; it is common in many beds of magnetite. When mounted like a horse-shoe magnet, a good lodestone will lift a weight of many pounds. This is the only mineral that has decided magnetic attraction. But several ores containing iron are *attracted* by the magnet, or, when brought near a magnetic needle, will cause it to vibrate; and moreover, the metals nickel, cobalt, manganese, palladium, platinum and osmium, have been found to be slightly magnetic.

Many minerals become attractable by the magnet after being heated that are not so before heating. This arises from a change of part or all of the iron to the magnetic oxide.

7. TASTE AND ODOR.

Taste belongs only to the soluble minerals; the kinds are—

1. *Astringent*—the taste of vitriol.
2. *Sweetish-astringent*—the taste of alum.
3. *Saline*—taste of common salt.

4. *Alkaline*—taste of soda.
5. *Cooling*—taste of saltpetre.
6. *Bitter*—taste of epsom salts.
7. *Sour*—taste of sulphuric acid.

Odor is not given off by minerals in the dry, unchanged state, except in the case of a few gases and soluble minerals. By friction, moistening with the breath, the action of acids and the blowpipe, odors are sometimes obtained, which are thus designated:

1. *Alliaceous*—the odor of garlic. It is the odor of burning arsenic, and is obtained by friction, and more distinctly by means of the blowpipe, from several *arsenical* ores.

2. *Horse-radish odor*—the odor of decaying horse-radish. It is the odor of burning selenium, and is strongly perceived when ores of this metal are heated before the blowpipe.

3. *Sulphureous*—odor of burning sulphur. Friction will elicit this odor from pyrites, and heat from many sulphides.

4. *Fetid*—the odor of rotten eggs or sulphuretted hydrogen. It is elicited by friction from some varieties of quartz and limestone.

5. *Argillaceous*—the odor of moistened clay. It is given off by serpentine and some allied minerals when breathed upon. Others, as pyrargillite, afford it when heated.

3. CHEMICAL PROPERTIES OF MINERALS.

THE chemical properties of minerals are of two kinds. (1) Those of the chemical composition of minerals, (2) those depending on their chemical reactions, with or without fluxes, including results obtained by means of the blowpipe.

1. CHEMICAL COMPOSITION.

All the elements made known by chemistry are found in minerals, for the mineral kingdom is the source of whatever living beings—plants and animals—contain or use. A list of these elements, as at present made out, is contained in the following table, together with the symbol for each used in stating the composition of substances. These symbols are abbreviations of the Latin names for the elements. A few of these Latin names differ much from the English, as follows:

Stibium	Sb	= Antimony	Kalium	K	= Potassium
Cuprum	Cu	= Copper	Argentum	Ag	= Silver
Ferrum	Fe	= Iron	Natrium	Na	= Sodium
Plumbum	Pb	= Lead	Stannum	Sn	= Tin
Hydrargyrum	Hg	= Mercury	Wolframium	W	= Tungsten

TABLE OF THE ELEMENTS.

Aluminum	Al	27·4	Columbium (Niobium)	Cb (Nb)	94
Antimony	Sb	120	Copper	Cu	63·4
Arsenic	As	75	Didymium	D	144·8
Barium	Ba	137	Erbium	E	168·9
Bismuth	Bi	210	Fluorine	F	19
Boron	B	11	Gallium	Ga	68 ?
Bromine	Br	80	Glucinum (Beryllium)	G (Be)	9·4
Cadmium	Cd	112	Gold	Au	197
Cæsium	Cs	133	Hydrogen	H	1
Calcium	Ca	40	Indium	In	113·4
Carbon	C	12	Iodine	I	127
Cerium	Ce	138	Iridium	Ir	198
Chlorine	Cl	35·5	Iron	Fe	56
Chromium	Cr	52 2	Lanthanum	La	139
Cobalt	Co	58·8	Lead	Pb	207

Lithium	Li	7	Silver	Ag	108
Magnesium	Mg	24	Silicon	Si	28
Manganese	Mn	55	Sodium	Na	23
Mercury	Hg	200	Strontium	Sr	87·6
Molybdenum	Mo	96	Sulphur	S	32
Nickel	Ni	58·8	Tantalum	Ta	182
Nitrogen	N	14	Tellurium	Te	128
Osmium	Os	199·2	Thallium	Tl	204
Oxygen	O	16	Thorium	Th	235
Palladium	Pd	106·6	Tin	Sn	118
Phosphorus	P	31	Titanium	Ti	50
Platinum	Pt	197·6	Tungsten	W	184
Potassium	K	39·1	Uranium	U	240
Rhodium	Ro	104·4	Vanadium	V	51·2
Rubidium	Rb	85·4	Yttrium	Y	92
Ruthenium	Ru	104·4	Zinc	Zn	65·2
Selenium	Se	79·4	Zirconium	Zr	89·6

The *combining weights* indicate the proportions in which the elements combine. Thus, assuming hydrogen, the lightest of the elements, to be 1, or the unit of the series, the combining weight of oxygen is 16; of iron, 56; of magnesium, 24; of sulphur, 32; and so on. When hydrogen and oxygen combine it is in the ratio of 2 pounds of hydrogen, or else 1 pound of hydrogen, to 16 pounds of oxygen, and two different compounds thus result. When oxygen and magnesium combine it is in the ratio of 16 pounds of oxygen to 24 of magnesium. Oxygen and iron combine in the ratio of 16 of oxygen to 56 of iron; or of 24 of oxygen (1½ times 16) to 56. Sulphur and oxygen combine in the ratio of 32 of oxygen to 32 of sulphur; or of 48 to 32 of sulphur. The combining weights are often called the *atomic* weights.

The following is the manner of using the symbols: For the compound consisting of hydrogen and oxygen in the ratio of 2 to 16, the chemical symbol is H_2O, meaning 2 of hydrogen to 1 of oxygen. (This compound is water.) For the compound of oxygen and magnesium just referred to, the symbol is MgO; for the two compounds of oxygen and iron, FeO, protoxide of iron; Fe_2O_3, sesquioxide of iron, the ratio of 1 to 1½ being expressed by 2 to 3; for the two compounds of sulphur and oxygen, SO_2 and SO_3.

Some of the elements so closely resemble one another that their similar compounds are closely alike in crystallization and other qualities, and they are therefore said to be *isomorphous.*

This is true of iron, magnesium, calcium, and two or three other related elements. In one group of compounds of these bases, the carbonates, the crystalline form for each is rhombohedral, and among them there is a difference of less than two degrees in the angle of the rhombohedron. Besides a carbonate of calcium, a carbonate of magnesium, and a carbonate of iron, there is also a *carbonate of calcium and magnesium*, in which *half* of the calcium of the first of these carbonates is replaced by half an atom of magnesium; and another species in which the base, instead of being all magnesium, is half magnesium and half iron. By *half* is here meant half in the proportion of their combining weights.

The replacement of one of these elements by the other, and similar replacements among other groups of related elements, run through the whole range of mineral compounds. Thus we have *sodium* replacing *potassium*, *arsenic* replacing *phosphorus* and *antimony*, and so on.

In the combinations of oxygen and iron, as illustrated above, oxygen is combined with the iron in different proportions. FeO contains 1 of Fe (iron) to 1 of O (oxygen) and Fe_2O_3, or, as it is often written, $\mathrm{\bar{F}eO_3}$, contains $\frac{2}{3}$ Fe to 1 of O. As the iron in each of these cases satisfies the oxygen, it is evident that the iron must be in two different states, (1) a *protoxide* state, and (2) a *sesquioxide* state. One part of iron in this sesquioxide state ($= \frac{2}{3}$ Fe) often replaces in compounds one part of iron in the protoxide state (or 1Fe), with no greater change of qualities than happens in the replacement of iron by magnesium, or calcium, explained above; or, avoiding fractions, 3 parts of Fe in the protoxide state replaces 2Fe in the sesquioxide state. Writing $\mathrm{\bar{F}e}$ for the last 2Fe, the statement becomes 1 of Fe_3 replaces 1 of $\mathrm{\bar{F}e}$. Aluminium occurs only in the sesquioxide state, and the ordinary symbol of the oxide is Al_2O_3, or $\mathrm{\bar{A}lO_3}$. But it is closely related to iron in the sesquioxide state, so that, using the same mode of expression as for iron, 1 of $\mathrm{\bar{A}l}$ replaces 1 of Fe_3, or 1 of Mg_3, and so on. Similarly, writing R for any metal, 1 of $\mathrm{\bar{R}}$ replaces 1 of R_3. Again, in potash (K_2O), soda (Na_2O), lithia (Li_2O), water (H_2O), one of oxygen (O) is combined severally with 2 of K (potassium), of Na (sodium), of Li (lithium), of hydrogen; and hence 2K, 2Na, 2Li, that is, K_2, Na_2, Li_2, may each replace in compounds 1Ca, or 1Mg, etc.

The elements *potassium*, *sodium*, *lithium*, *hydrogen*, of which it takes two parts to combine with 1 of oxygen, are called monads. Other elements of the group of monads are *rubidium*, *cæsium*, *thallium*, *silver*, and also *fluorine*, *chlorine*, *bromine*, *iodine*. Still other elements combining by two parts in their oxygen or sulphur compounds, etc., are nitrogen, phosphorus, antimony, boron, columbium, tantalum, vanadium, gold. For example, for arsenic there are the compounds As_2S, As_2S_3, As_2O_3, As_2O_5, etc. Another characteristic of these elements of the hydrogen, sodium, chlorine, and arsenic groups is that the number of equivalents of the acidic element in the compounds into which they enter is, with a rare exception, *odd*, and of the 1, 3, 5, etc., series, and on this account they are called in chemistry *perissads*; while the other elements, in whose compounds their number is of the 1, 2, 3, etc. (or 2, 4, 6) series, are called *artiads*. An apparent exception exists under the artiads in the sesquioxides, but this does not alter the general character of the series.

The facts above cited sustain the general statement that Ca_3, Mg_3, Mn_3, Zn_3, Fe_3, Al, Fe, Mn, have equivalent combining values, and hence in minerals often replace one another; and so also Ca, Mg, Mn, Zn, Fe, K_2, Na_2, Li_2, H_2, may replace one another. Similarly, also, As_2, or Sb_2 replaces S in some minerals.

With reference to the classification of minerals the elements may be conveniently divided into two groups: (1) the *Acidic*, and (2) the *Basic*. The former includes oxygen and the elements which were termed the *acidifiers* and *acidifiable* elements in the old chemistry. They are those which have been called in mineralogy the *mineralizing* elements, since they are the elements which are found combined with the metals to make them ores, that is, to mineralize them. The basic are the rest of the elements. The groups overlap somewhat, but this need not be dwelt upon here.

The more important of the acidic elements are the following: oxygen, fluorine, chlorine, bromine, iodine, sulphur, selenium, tellurium, boron, chromium, molybdenum, tungsten, phosphorus, arsenic, antimony, vanadium, nitrogen, tantalum, columbium, carbon, silicon.

Again, among the compounds of these elements occurring in the mineral kingdom there are two grand divisions, the *binary* and the *ternary*. The binary consist of one or more elements of each of the acidic and basic divisions, and the ternary of one or more elements of each of these two classes, along with oxygen, fluorine, or sulphur as a third. The binary include the *sulphides*, *arsenides*, *chlorides*, *fluorides*, *oxides*, etc., and the ternary the *sulphates*, *chromates*, *borates*, *arsenates*, *phosphates*, *silicates*, *carbonates*, etc., and also the *sulph-arsenites* and *sulph-antimonites*, in which a basic metal (usually lead, copper, silver) is combined with arsenic or antimony and sulphur.

The following are examples of the symbols of binary and ternary compounds:

1. *Binary.*

1. *Sulphides, Selenides.*—Ag_2S = silver sulphide; Ag_2Se = silver selenide; PbS = lead sulphide; ZnS = zinc sulphide; FeS_2 = iron disulphide.

2. *Fluorides, Chlorides*, etc.—CaF_2 = calcium fluoride; $AgCl$ = silver chloride; $AgBr$ = silver bromide; AgI = silver iodide; $NaCl$ = sodium chloride (common salt).

3. *Oxides.*—$Al_2O_3 = 3(Al_{\frac{2}{3}}O)$ = aluminium sesquioxide; As_2O_3 = arsenic trioxide; As_2O_5 = arsenic pentoxide; BaO = barium oxide; B_2O_3 = boron trioxide (boracic acid); CaO = calcium oxide (lime); CO_2 = carbon dioxide (carbonic acid); CrO_3 = chromium trioxide (chromic acid); Cu_2O = copper suboxide; CuO = copper oxide; BeO = beryllium oxide; H_2O = hydrogen oxide (water); FeO = iron oxide; Fe_2O_3 = iron sesquioxide; PbO = lead oxide; Li_2O = lithium oxide; MgO = magnesium oxide; MnO = manganese oxide; Mn_2O_3 = manganese sesquioxide; MnO_2 = manganese dioxide; P_2O_5 = phosphorus pentoxide; K_2O = potassium oxide; SiO_2 = silicon dioxide (silica); Na_2O = sodium oxide; SrO = strontium oxide; SO_2 = sulphur dioxide (sulphurous acid); SO_3 = sulphur trioxide; SnO_2 = tin dioxide; V_2O_5 = vanadium pentoxide (vanadic acid); WO_3 = tungsten trioxide (tungstic acid); ZnO = zinc oxide; ZrO_2 = zirconium dioxide.

The composition of these compounds may be obtained from the table of combining weights, page 76. For example, with reference to the first of them (AgS), the table gives for the combining weight of silver (Ag), 108, and for that of sulphur, 32. The elements exist in the compound therefore in the proportion of 108 to 32, and from it the composition of a hundred parts is easily deduced.

If the formula were $(Ag, Pb)S$, signifying a silver-and-lead sulphide, and if the silver and lead were in the ratio of 1 to 1, then half the combining weight of silver is taken; that is, 54, and half the atomic weight of lead, which is 103·5; and the sum of these numbers, with 32 for the sulphur, expresses the ratio of the three ingredients.

For Al_2O_3 we find the combining weight of aluminium 27.4; doubling this for Al_2 makes 54·8. Again, for oxygen, we find 16; and three times 16 is 48. 54·8 to 48 is therefore the ratio of aluminium to the oxygen in Al_2O_3, from which the percentage proportion may be obtained.

2. *Ternary Oxygen Compounds.*

Silicates.—Of these compounds there are two prominent groups. In one of these groups the general formula is RO_3Si, and in the other R_2O_4Si. In both of these formulas R stands for any basic elements in the protoxide state, as Ca, Mg, Fe, etc., either alone or in combination. In the first of these formulas the combining values of the basic element R and the acidic element or silicon, as measured by their combinations with oxygen, are in the proportion of 1 to 2, for R stands for an element in the *protoxide* state, while Si stands for silicon, which is in the *dioxide* state, its oxide being a dioxide: and hence the minerals so constituted are called *Bisilicates.* In the second of these formulas this ratio is 2 to 2, or 1 to 1, and hence these are called *Unisilicates.*

Multiplying these formulas by 3, they become $R_3O_9Si_3$, and $(2R_3)O_{12}Si_3$; and the same composition is expressed. In this form the substitution of sesquioxide bases for protoxide may be indicated: thus, $R_3\bar{R}\,O_{12}Si_3$ signifies that half of the $2R_3$ is replaced by $\bar{Al}$ or $\bar{Fe}$, or some other element in the sesquioxide state.

There are also some species in which the ratio is 1 to less than 1, and these are called *Subsilicates.*

The ratio here referred to (formerly known as the oxygen ratio) is called the *quantivalent ratio.*

The other ternary compounds require no special remarks in this place.

2. CHEMICAL REACTIONS.

1. *Trials in the wet way.*

1. *Test for Carbonates.*—Into a test tube put a little hydrochloric acid diluted with one half water, and add a small portion in powder of the mineral. If a carbonate, there will be a brisk effervescence caused by the escape of carbonic dioxide (carbonic acid), when heat is applied, if not before. With calcium carbonate no heat or pulverization is necessary.

2. *Test for Gelatinizing Silica.*—Some silicates, when pow

dered and treated with strong hydrochloric acid, are decomposed and deposit the silica in a state of a jelly. The experiment may be performed in a test tube, or small glass flask. Sometimes the evaporation of the liquid nearly to dryness is necessary in order to obtain the jelly. Some silicates do not afford the jelly unless they have been previously ignited before the blowpipe, and some gelatinizing silicates lose the power on ignition.

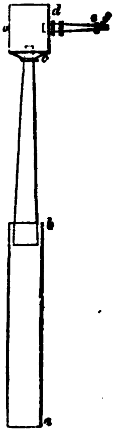
3. *Decomposability of Minerals by Acids.*—To ascertain whether a mineral is decomposable by acids or not, it is very finely powdered and then boiled with strong hydrochloric acid, or, in case of many metallic minerals, with nitric acid. In some cases where no jelly is formed there is a deposit of silica in fine flakes. With the sulphides and nitric acid there is often a deposit of sulphur, which usually floats upon the surface of the fluid as a dark spongy mass. Some oxides, and also some sulphates and many phosphates, are soluble entirely without effervescence. But many minerals resist decomposition. It is sometimes difficult to tell whether a mineral is decomposed with the separation of the silica or whether it is unacted upon. In such a case a portion of the clear fluid is neutralized by soda (sodium carbonate), and if anything has been dissolved it will usually be precipitated.

Test for Fluorine.—Most fluorides are decomposed by strong heated sulphuric acid, give out fluorine which will etch a glass plate in reach of the fumes. The trial may be made in a lead cup and the glass put over it as a loose cover.

2. *Trials with the Blowpipe.*

The blowpipe, in its simplest form, is merely a bent tube of small size, eight to ten inches long, terminating at one end in a minute orifice. It is used to concentrate the flame on a mineral, and this is done by blowing through it while the smaller end is just within the flame.

The annexed figure represents the form commonly employed, except that the tube is usually without the division at *b*. It contains an air chamber (*o*) to receive the moisture which is condensed in the tube during the blowing; the moisture, unless thus removed, is often blown through the small aperture and interferes with the experiment. The jet, *ef*, is movable, and it is desirable that it should be made of platinum, in order that it may be cleaned when necessary, either by high heating or by immersion in an acid. The screw at *b* is for the purpose of shortening the tube one-half so as to make it more convenient for the pocket of the field mineralogist. It is unscrewed for this purpose, and the smaller part put within the larger.



In using the blowpipe it is necessary to breathe and blow at the same time, that the operator may not interrupt the flame in order to take breath. Though seemingly absurd, the necessary tact may easily be acquired. Let the student first breathe a few times through his nostrils while his cheeks are inflated and his mouth closed. After this practice let him put the blowpipe to his mouth and he will find no difficulty in breathing as before while the muscles of the inflated cheeks are throwing the air they contain through the blowpipe. When the air is nearly exhausted the mouth may again be filled through the nose without interrupting the process of blowing.

The flame of a candle, or a lamp with a large wick may be used, and when so it should be bent in the direction the flame is to be blown. But it is far better, when gas can be had, to use a Bunsen's burner.

The flame has the form of a cone, yellow without and blue within. The heat is most intense just beyond the extremity of the blue flame. In some trials it is necessary that the air should not be excluded from the mineral during the experiment, and when this is the case the *outer* flame is used. The outer is called the *oxidizing* flame (because oxygen, one of the constituents of the atmosphere, combines in many cases with some parts of the assay, or substance under experiment), and the inner the *reducing* flame. In the latter the carbon and hydrogen of the flame, which are in a high state of ignition, and which are enclosed from the atmosphere by the outer flame, tend to unite with the oxygen of any substance that is inserted in it. Hence substances are reduced in it.

The mineral is supported in the flame either on charcoal; or by means of steel forceps (as in the annexed figure) with platinum extremities (*a b*), opened by pressing on the pins *p p*; or on platinum wire or foil.

To ascertain the *fusibility* of a mineral, the fragment for the platinum forceps should not be larger than the head of a pin, and, if possible, should be thin and oblong, so that the extremity may project beyond the platinum. The fusible metals alloy readily with platinum. Hence compounds of lead, arsenic, antimony, etc., must be guarded against. These compounds are tested on charcoal. The forceps should not be used with the fluxes, but instead either charcoal or the platinum wire or foil.

The *charcoal* should be firm and well burnt; that of soft wood is the best. It is employed especially for the reduction of oxides, in which the presence of carbon is often necessary, and also for observing any substances which may pass off and be deposited on the charcoal around the assay. These coatings are usually oxides of the metals, which are formed by the oxidation of the volatile metals as they issue from the reduction flame.

The platinum wire is employed in order to observe the action of the fluxes on the mineral, and the colors which the oxides impart to the fluxes when dissolved in them. The wire used is No. 27. This is cut into pieces about three inches long, and the end is bent into a small loop, in which the flux is fused. This makes what is called a bead. When the experiment is complete the beads are removed by uncoiling the loop and drawing the wire through the finger nails. After use for awhile the end breaks off, because platinum is acted upon by the soda, and then a new loop has to be made. Dilute sulphuric acid will remove any of the flux that may remain upon it after a trial has been made.

Glass tube is employed for various purposes. It should be from a line to a fourth of an inch in bore. It is cut into pieces four to six inches long, and used in some cases with both ends open, in others with one end closed. In the *closed* tube, either heated directly over the Bunsen burner, or with the aid of the blowpipe, volatile substances in the assay are vaporized and condensed in the upper colder part of the tube, where they may be examined by a lens if necessary, or by further heating. The odor given off may also be noted, and the acidity of any fumes by inserting a small strip of litmus paper in the mouth of the tube. The closed tube is used to observe all the effects that may take place when a substance is heated out of contact with the air. In the *open* tube the atmosphere passes through the tube in the heating, and so modifies the result. The assay is placed an inch or an inch and a quarter from the lower end of the tube; the tube should be held nearly horizontally, to prevent the assay from falling out. The strength of the draught depends upon the inclination of the tube, and in special cases it should be inclined as much as possible.

The most common *fluxes* are *borax* (sodium bi-borate), *salt of phosphorus* (sodium and ammonium phosphate), and *soda* (sodium carbonate, either the carbonate or bi-carbonate of soda of the shops.) These substances, when fused and highly heated, are very powerful solvents for metallic oxides. They should be pure preparations. The borax and soda are much the most important. In using the platinum wire, the loop may be highly heated, and then a portion of the borax or soda may be taken up by it, and by successive repetitions of this process the requisite amount of the flux may be obtained on the wire. Then, by bringing the melted flux of the loop into contact with one or more grains of the pulverized mineral, the assay is made ready for the trial. With soda and quartz a perfectly clear globule is obtained, cold as well as hot, if the flux is used in the right proportion. Some oxides impart a deep and characteristic color to a bead of borax. In other cases the color obtained is more characteristic when salt of phosphorus is employed. The color obtained in the outer flame is often different from that which is obtained in the inner flame. The beads are sometimes transparent and sometimes opaque. If too much substance is employed the beads will be opaque when it is desired that they should be transparent. In such cases the experiment may be repeated with less substance. In many cases pulverized mineral and the flux, a little moistened, are mixed together into a ball upon charcoal, especially in the experiments with soda.

In the examination of sulphides, arsenides, antimonides and related ores, the assay should be *roasted* before using a flux, in order to convert the substance into an oxide. This is done by spreading the substance out on a piece of charcoal and exposing it to a gentle heat in the oxidizing flame. The sulphur, arsenic, antimony, etc., then pass off as oxides in the form of vapors, leaving the non-volatile metals behind as oxides. The escaping sulphurous acid gives the ordinary odor of burning sulphur; arsenous acid, from arsenic present, the odor of garlic, or an alliaceous odor; selenous acid, from selenium present, the odor of decaying horse-radish; while antimony fumes are dense white, and have no odor.

The following is the *scale of fusibility* which has been adopted, beginning with the most fusible:

1. Stibnite.—Fusible in large pieces in the candle flame.

2. **Natrolite.**—Fusible in small splinters in the candle flame.

3. **Almandine**, or bright red **garnet.**—Fusible in large pieces with ease in the blowpipe flame.

4. **Actinolite.**—Fusible in large pieces with difficulty in the blowpipe flame.

5. **Orthoclase**, or common feldspar. Fusible in small splinters with difficulty in the blowpipe flame.

6. **Bronzite.**—Scarcely fusible at all.

The *color of the flame* is an important character in connection with blowpipe trials. When the mineral contains *sodium* the color of the flame is deep yellow, and this is generally true in spite of the presence of other related elements. When sodium (or soda) is absent, *potassium* (or potash) gives a pale violet color; *calcium* (or lime) a pale reddish yellow; *lithium*, a deep purple-red, as in lithia-mica; *strontium*, a bright red, this element being the usual source of the red color in pyrotechny; *copper*, emerald green; *phosphates*, bluish green; *boron*, yellowish green; *copper chloride*, azure blue. Beads should be examined by daylight only, and should be held in such position that the color is not modified by green trees or other bright objects when examined by transmitted light. Colored flames are seen to best advantage when some black object is beyond the flame in the line of vision.

It is also to be noted, in the trials, whether the assay heats up quietly, or with decrepitation; whether it fuses with effervescence or not, or with intumescence or not; whether it fuses to a bead which is transparent, clouded, or opaque; whether blebby (containing air-bubbles or not); whether scoria-like or not.

Testing for Water.—The powdered mineral is put at the bottom of a closed glass tube, and after holding the extremity for a moment in the flame of a Bunsen's burner, moisture, if any is present, will have escaped and be found condensed on the inside of the tube, above the heated portion. Litmus or turmeric paper is used to ascertain if the water is acid or alkaline, acids changing the blue of litmus paper to red, and alkalies the yellow of turmeric paper to brown.

Testing for an Alkali.—If the fragment of a mineral, heated in the platinum forceps, contains an alkali, it will often, after being highly heated, give an alkaline reaction when placed, after moistening, on turmeric paper, turning it brown. This test is applicable to those salts which, on heating, part with a portion of their acid and are rendered caustic thereby. Such are the carbonates, sulphates, nitrates, and chlorides of the alkaline metals.

Testing for Alumina or Magnesia.—Cobalt nitrate, in solution, is used to distinguish an infusible and colorless mineral containing aluminium from one containing magnesium. A fragment of the mineral is first ignited, and then wet with a drop or two of the cobalt solution and heated again. The aluminium mineral will assume a blue color, and the magnesium mineral a pale red or pink.

Any fusible silicate, when moistened with cobalt nitrate and ignited will assume a blue color, hence this test is only decisive in testing infusible substances.

Infusible *zinc* compounds, when moistened with cobalt nitrate, assume a green color.

Testing for Lithium.—Some lithium minerals give the bright purple-red flame if simply heated in the platinum forceps. In other cases mix the powdered mineral with one part of fluorite and one of potassium bi-sulphate. Make the whole into a paste with a little water, and heat it on the platinum wire in the blue flame.

Testing for Boron.—When the bright yellow-green of boron is not obtained directly on heating the mineral containing it, one part of the powdered mineral should be mixed with one part of powdered fluorite and three of potassium bi-sulphate; and then treated as in the last. The green color appears at the instant of fusion.

Testing for Fluorine.—To detect fluorine in fluorides mix a little of the powdered substance with potassium bi-sulphate, put the mixture in a closed glass tube and fuse gently. The bi-sulphate gives off half of its sulphuric acid at a high temperature, which acts powerfully on anything it can attack. If a fluoride is present, hydrofluoric acid will be given off, and the walls of the tube will be found roughened and etched when the tube is broken open and cleaned after the experiment. If a silicate containing fluorine be powdered and mixed with previously fused salt of phosphorus, and heated in the open tube by blowing the flame into the lower end of the tube, hydrofluoric acid is given off, and the tube is corroded just above the assay.

Silicates.—Nearly all silicates undergo decomposition with salt of phosphorus, setting free the silica, forming a bead which is clear while hot and has a skeleton of silica floating in it. The bead is sometimes clear also when cold.

Iron.—Minerals containing much iron produce a magnetic globule when highly heated. Usually the reducing flame is required, and sometimes the use of soda. With borax iron gives a bead with the oxidizing flame which is yellow while hot, but colorless on cooling, and which in the reducing flame becomes bottle green.

Cobalt.—Minerals containing cobalt afford, with borax, a beautiful blue bead. If sulphur or arsenic is present it should be first roasted off on charcoal.

Nickel.—In the oxidizing flame with borax, the bead is violet when hot, and red-brown on cooling. In the reducing flame the glass becomes gray and turbid from the separation of metallic nickel, and on long blowing, colorless. The reaction is obscured by the presence of cobalt, iron, and copper.

Manganese.—With borax in the oxidizing flame, the bead is a deep violet-red, and almost black if too much of the mineral is used. To see the color examine by transmitted light. With soda in the same flame the opaque bead is bluish green.

Chromium.—With borax, both in the oxidizing and reducing flame, the bead is bright emerald green.

Titanium.—Titanium oxide with salt of phosphorus on platinum wire in O.F. dissolves to a clear glass, which, if much is present, becomes yellow while hot and colorless on cooling; but in R.F. the hot globule obtained in O.F. reddens and assumes finally a beautiful violet color. On charcoal with tin the glass becomes violet if there is not too much iron present.

Zinc.—Zinc and some of its compounds when heated cover the charcoal with zinc oxide, which is yellow while hot, but white on cooling; and this coating, if wet with cobalt solution and then heated, assumes a fine yellowish-green color which is most distinct when cold.

Lead, *copper*, *tin*, *silver*, when characterizing a mineral, give with soda in the reducing flame minute metallic globules, which are malleable, or may be cut with a knife; they can be distinguished by their well-known physical properties. When two or more of these metals occur together, or iron is also present, the globules consist usually of an alloy of the metals.

Lead.—When the mineral is treated with soda on charcoal in the oxidizing flame, the yellow oxide coats the charcoal around the assay.

Copper.—The flame is colored, in most cases, bright green. With borax or salt of phosphorus in the reducing flame the bead is red. In the oxidizing flame the bead is green when hot and becomes blue or greenish blue on cooling.

Mercury.—Heated in the closed tube with soda, a sublimate of metallic mercury covers the inside of the tube.

Silver.—If the silver is in very small quantities, as in argentiferous galena, the assay is put into a little cup made of bone ashes (bone burnt white and finely pulverized), and subjected to the oxidizing flame; the lead is oxidized and sinks into the bone ashes, leaving the silver a brilliant globule on the cupel. Before cupellation it is often necessary to melt the assay together with some borax and pure lead in a hole on charcoal. By this process the sand and impurities are removed, and a globule of lead is obtained which contains all the silver, and which may be separated from the slag and be oxidized as above.

Arsenic.—In the closed tube arsenic sublimes and coats the tube with brilliant grains, or a crust, of metallic arsenic. If the mineral contains sulphur as well as arsenic, sublimates of the yellow and red arsenic sulphides (orpiment and realgar) are often formed. In the open tube a sublimate of white arsenous acid is formed, which condenses in bright crystals on the walls of the tube, and a strong garlic odor is given off. On charcoal the alliaceous odor is at once perceptible.

Antimony.—In the closed tube, when sulphur is present, the assay yields a sublimate which is black when hot, brown-red when cold. In the open tube dense white vapors are given off and a white *amorphous* sublimate covers the inside of the tube, which, for the most part, does not volatilize when reheated. On charcoal the assay yields dense, white, inodorous fumes.

Tellurium.—In the open tube a white or grayish sublimate is obtained, which may be fused to *clear, colorless drops.* On charcoal a white coating is produced, and the reducing flame is colored green.

Sulphur.—All sulphates, and other sulphur-bearing minerals, when heated on charcoal with soda, produce a dark, yellowish brown sulphide of sodium; and if a fragment of this is moistened and placed on a polished plate of silver, it turns it immediately brownish black, or black. Pure soda, and a flame wholly free from sulphur, is needed for the trial, since the least trace of sulphur in either vitiates the result. Many sulphides give fumes of sulphur on charcoal. The higher sulphides afford these fumes in a closed tube. The others afford fumes of sulphurous acid in an open tube, which redden a moistened blue litmus paper placed in the upper end of the tube.

Selenium.—Selenium and many selenides afford a steel-gray sublimate in an open tube, which at the upper edge appears red. On charcoal brown fumes are given off with an odor like that of decaying horse-radish.

Chlorides.—If a bead of borax be saturated with copper oxide, and then dipped into the powder of a substance which is to be tested for chlorine, a chloride of copper is formed which imparts an azure blue color to the flame if any chlorine is present. If dissolved in water or nitric acid a little silver nitrate produces a dense white precipitate of silver chloride.

Nitrates.—A nitrate, if fused on charcoal, will deflagrate with brilliancy, owing to the decomposition of the nitrate and the union of its oxygen with the carbon.

Phosphates.—Phosphates give a dirty green color to the blowpipe flame. The color is more distinct if the substance is first moistened with sulphuric acid. If a phosphate is pulverized and heated in a closed glass tube with some bits of magnesium wire, the phosphoric acid is reduced, and when the fusion is moistened with water the very disagreeable odor of phosphuretted hydrogen is obtained.

For a full account of blowpipe reactions recourse must be had to a treatise on the blowpipe. The best and fullest American work on the subject is Prof. G. J. Brush's "Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis."

In this work the following abbreviations are used in speaking of blowpipe reactions:

B.B. = before the blowpipe; *O.F.* = oxidizing flame; *R.F.* = reducing flame.

4. DESCRIPTIONS OF MINERALS.

CLASSIFICATION.

SOME of the prominent points in the classification of minerals adopted in the following pages are given in connection with the remarks on chemical composition, pages 79.

Many instructors in the science, and most of those who consult a work on Mineralogy for practical purposes, prefer an arrangement of the ores which groups them under the head of the metal prominent in their constitution. The method of grouping mineral species according to the basic element has therefore been here, to a large extent, followed. An exception has been made in the case of the silicates, because it is with them almost impracticable, on account of the number of basic elements they often contain; and, moreover, not more than half a dozen useful ores exist among them. The silicates therefore, which include the larger part of all minerals, make together one of the grand divisions in the classification, and they are presented according to their natural groups, in the same order as in the larger mineralogy.

The prominent subdivisions in the classification are as follows:

I. THE ACIDIC DIVISION, including the acidic elements occurring native, and the native compounds of the acidic elements with one another.

II. THE BASIC DIVISION, including the basic elements occurring native, and the native binary and ternary compounds of the basic elements—the silicates excepted.

III. SILICA and the SILICATES.

IV. THE HYDROCARBON COMPOUNDS, including mineral oils, resins, wax, and coals.

The following are the chief subdivisions under these heads:

I. ACIDIC DIVISION.

1. Sulphur Group.—The chief oxide a trioxide, its formula RO_3. Includes Sulphur and sulphur oxides; Tellurium and tellurium oxides; Molybdenum sulphide and oxide; Tungsten oxide.

2. Boron Group.—The chief oxide a trioxide, its formula R_2O_3. Includes compounds of Boron with oxygen.

3. Arsenic Group.—The chief oxide a pentoxide, its formula R_2O_5. Includes Arsenic and arsenic sulphides and oxides; Antimony and antimony sulphide, arsenide and oxides; Bismuth and bismuth sulphide, telluride and oxide.

4. Carbon Group.—The chief oxide a dioxide, its formula RO_2. Includes Carbon (Diamond, Graphite) and carbon dioxide. (Quartz, SiO_2, belongs here chemically, but is placed with the Silicates.)

II. BASIC DIVISION.

Gold; Silver; Platinum and Iridium; Palladium; Quicksilver; Copper; Lead; Zinc; Cadmium; Tin; Titanium; Cobalt and Nickel; Uranium; Iron; Manganese; Aluminium; Cerium, Yttrium, Lanthanum, Didymium and Erbium; Magnesium; Calcium; Barium and Strontium; Potassium and Sodium; Ammonium; Hydrogen.

III. SILICA AND SILICATES.

1. Silica.
2. Anhydrous Silicates.
    1. Bisilicates.
    2. Unisilicates.
    3. Subsilicates.
3. Hydrous Silicates.
    1. General section of Hydrous Silicates.
    2. Zeolite section.
    3. Margarophyllite section.

IV. HYDROCARBON COMPOUNDS.

1. Oils, Resins, Wax.
2. Asphaltum, Coals.

GENERAL REMARKS ON ORES.

An ore, in the mineralogical sense of the word, is a mineral compound in which a metal is a prominent constituent. In the

CONDITIONS OF METALS AND THEIR ORES IN NATURE.

Metals very rarely occur in nature perfectly *pure*: gold is said to do so, but there is no recorded instance of any occurring in nature without silver. (*All* commercial lead contains silver.) Metals are said to occur *native* when found in the metallic state, i. e., pure or as alloys,—mineralized, when they occur combined with metalloids. Bi, Au, and the platinoids (?) mostly occur native. Native Ag, Cu and Hg are often abundant. Fe, Ni and Co—except in the commercially unimportant instances of meteorites, and certain trap dikes in the case of Fe,—occur mineralized.

Metallic ores are natural compounds which may be availably worked for obtaining their respective metals. The most common ores are oxides, carbonates and sulphides,—arsenides, silicates, and more rarely chlorides occur. Ores are frequently so disguised by mixtures with other ores or material as to deceive all but experts. One of the most valuable iron ores,—the "black band" of the English miners—often is so mixed with earthy and carbonaceous matters as to appear worthless to one acquainted only with cabinet specimens—rendering it doubtful whether cabinets of exhibition do more good than harm, industrially. Sometimes ores have dispersed all through them injurious compounds of P, As, and S so intimately blended as to greatly increase the difficulty of their mechanical removal, and without this separation their chemical metallurgy is so complex as often to forbid financial success. In other cases we find mixtures of ores less closely associated, the several ores being scattered through the gangue, plainly visible. Even in hand specimens, cobalt, nickel and silver ores, and especially lead, zinc and copper sulphides so occur together, as will be seen in the *trays.*

The distribution of ores in rock strata is not at random, nor uniformly diffused, bnt in beds or seams between the rock strata; this is eminently so with iron ores, and often with lead ores, each "seam" and "stratum" having once been the outer one; the *texture* of the rock often indicating the species of iron ore found in it. Again, the ores occur scattered, not throughout the whole rock but in restricted spaces, in grains, nests, concretions or spread-out masses—e. g., cinnabar and some ores of iron. In other cases they occur occupying fissures called veins, cutting through rocks at all angles. Most ores so occur—as just stated—also on intercalated sheet p. 60, Geology, Iron is a marked exception. Often ores occur in rocks near where they are cut through by trap dikes—the trap dike itself containing the disseminated ores; e. g., the rock and trap in the Michigan copper country. When such scattered ore is malleable the FILE detects it, as in the trays.

Gangue. The ore often forms a small part ot the vein—in case of rare metals only a very small part,—the gangue occupying the remainder. Frequently the metal entirely disappears, and for a long distance. If followed down the vein may become rich again, and is then said to be in "bonanza" (in Spanish speaking countries.) When ore reappears it is not always the same as above. The most common gangues=veinstones=matrix, are calcite, quartz, fluorite and heavy spar ($BaSC^4$.)

In the *Reduction of the ore*, i. e., obtaining the metal in its commercial state, both mechanical and chemical means are used. In the process of mining and selecting the ore, much of the gangue is rejected. Most of the balance is separated by crushing with hammers, stamps or rollers, and then "washing" in running water, or by making use of the sorting power of water.

Operating with a native fusible metal, e. g., bismuth, or a fusible ore, e. g., stibnite, ($Sb^2 S^3$) after crushing, heat alone is necessary to separate the gangue. Again, heat in the presence of air causes cinnabar and galena to give up their respective metals; or the S, in order to prevent the contamination of the atmosphere, may be absorbed by iron or lime. Often roasting is resorted to in order to form oxides, and then using the deoxidizing power of carbon which would be inert on a sulphide. Zinc being volatile, its silicate 2(ZnO). SiO^2 yields its metal by heat and carbon.

The method of obtaining gold and silver depends largely upon their solubility in mercury. In the case of *argentiferous* galena *cupellation* (?) is resorted to. (Min'y p. 89.

When the gangue is intimately blended, and sometimes when it is not so, as in the iron ores, a *flux* is used, its nature depending upon that of the gangue—if it is an acid (e. g. SiO^2) we use a base as lime, if it is basic we use an acid.

The resulting *slags* and *scorias* often greatly resemble certain volcanic products—sometimes containing *pyroxene* even,

In addition to these very general methods, others dependent upon some particular character of the ore or of the metal are resorted to.

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miner's use of the term it is a mineral substance that yields, by metallurgical treatment, a valuable metal, and especially when it profitably yields such a metal. In the former sense, galena, the common ore of lead, is, if it contains a little silver, an *argentiferous* lead-ore; while, in the latter, if there is silver enough to make its extraction profitable, it is a silver-ore. Further than this, where a native metal, or other valuable metallic mineral, is distributed intimately through the gangue, the mineral and gangue together are often called the ore of the metal it produces.

We have beyond to do with ores only in the mineralogical sense.

Ores are compounds of the metals, not metals in the native state. The more common kinds are compounds of the metals with *Sulphur* (sulphides); with *Arsenic* (arsenides); with *Sulphur* and *Arsenic* (sulph-arsenides); with sulphur in ternary combination along with arsenic, antimony or bismuth (making compounds called sulph-arsenites, sulph-antimonites, sulpho-bismutites); with *Selenium* (selenides); with *Tellurium* (tellurides); with *Oxygen* (oxides); with *Chlorine*, *Iodine*, or *Bromine* (chlorides, iodides, or bromides); with oxygen in ternary combination with carbon (making carbonates); with *Sulphur* (making sulphates); with *Arsenic* (making arsenates); with *Phosphorus* (making phosphates); with *Silicon* (making silicates).

Gold and platinum are, with rare exceptions, found only native, or intimately mixed in essentially the pure state with some metallic minerals. Tellurium is the only acidic element that occurs combined with gold in nature.

Silver is found in the state of sulphide, antimonide, selenide, telluride, sulph-arsenites and sulph-antimonites, but never as oxide or in oxygen ternary compounds.

Quicksilver occurs in the state of sulphide (the common ore); also in that of selenide and sulph-arsenites.

Copper and lead occur in the state of sulphides (common ores), and also in all the binary and ternary states mentioned above.

Zinc is known in the state of sulphide (very common), oxide, carbonate, sulphate, silicate (all, excepting the sulphate, valuable as ores); and *Cadmium* in that of sulphide only.

Tin occurs in the state of oxide (the common ore), and sulphide.

Cobalt and *Nickel* occur in the states of sulphide, arsenide, sulph-arsenides, antimonide, oxide, sulphate, arsenate, carbonate; and nickel in that also of a silicate.

Iron occurs in the state of sulphide (very common, but not useful as an ore of iron), of arsenide, sulph-arsenide, oxide (the common ores of iron), carbonate (useful ore), sulphate, arsenate, phosphate, silicate.

Manganese occurs in the state of sulphide (rare), arsenide (rare), oxide (the common ores), carbonate, sulphate, phosphate, silicate.

I. MINERALS CONSISTING OF THE ACIDIC ELEMENTS.

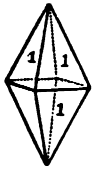
Oxygen might properly be included in this section, since it occurs native in the atmosphere mixed with nitrogen, constituting 21 per cent. of it. But this mention of it is all that is necessary. The ternary compounds, in which, as in sulphuric acid, hydrogen is the basic element, are here included. Chlorine, bromine, and iodine do not occur native, and neither do their oxides, nor any compounds with acidic elements, and hence these elements are not represented under this division. The same is true of selenium and chromium of the sulphur group, and of vanadium, tantalum, and columbium of the arsenic group.

I. SULPHUR GROUP.

Native Sulphur.

Trimetric.—In acute octahedrons, and secondaries to this form, with imperfect octahedral cleavage. $1 \wedge 1$ (in same pyramid) = 106° 25′ and 85° 07′; $1 \wedge 1$ (over base) = 143° 23′. Also massive.

1.



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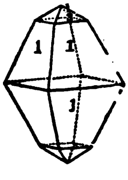


Color and streak sulphur-yellow, sometimes orange-yellow.

Lustre resinous. Transparent to translucent. Brittle. H. = 1·5—2·5. G. = 2.07. Burns with a blue flame and sulphurous odor. In a closed tube it is wholly volatilized and redeposited on the wall of the tube.

Native sulphur is either pure, or contaminated with clay or bitumen. It sometimes contains selenium, and has then an orange-yellow color.

Diff. It is easily distinguished by its burning with a blue flame, and the sulphur odor then afforded.

Obs. The great repositories of sulphur are either beds of gypsum and the associate rocks, or the regions of active or extinct volcanoes. In the valley of Noto and Mazzaro in Sicily, at Conil near Cadiz in Spain, Bex in Switzerland, and Cracow in Poland, it occurs in the former situation. Sicily and the neighboring volcanic islands, Vesuvius and the Solfatara in its vicinity, Iceland, Teneriffe, Java, Hawaii, New Zealand, Deception Island, and most active volcanic regions afford more or less sulphur. The native sulphur of commerce is brought largely from Sicily, where it occurs in beds along the central part of the south coast and to some distance inland. It undergoes rough purification by fusion before exportation, which separates the earth and clay with which it occurs.

On the Potomac, twenty-five miles above Washington, sulphur has been found associated with calcite in a gray compact limestone; sparingly about springs where hydrogen sulphide is evolved, in New York and elsewhere; in cavities where iron sulphides have decomposed, and in many coal mines; near Borax Lake, in California; Inferno, Humboldt County, Nevada, abundant.

The sulphur of commerce is also largely obtained from copper and iron pyrites, it being given off during the roasting of these ores.

Sulphur when cooled from fusion, or above 232° F., crystallizes in *oblique* rhombic prisms. When poured into water at a temperature above 300° F. it acquires the consistency of soft wax, and is used to take impressions of gems, medals, etc., which harden as the sulphur cools. The uses of sulphur for gunpowder, bleaching, the manufacture of sulphuric acid, and also in medicines, are well known. Sulphur occurs in various ores as sulphides and sulphates. Among the sulphides are *pyrite*, an iron sulphide; *pyrrhotite*, another iron sulphide; *galena*, a lead sulphide, the common ore of lead; *chalcopyrite*, or yellow copper ore, a copper and iron sulphide; *cinnabar*, a mercury sulphide; *argentite*, a silver sulphide, etc.

Sulphuric and Sulphurous Acids.

Sulphuric acid is occasionally met with around volcanoes, and it is also formed from the decomposition of hydrogen sulphide about sulphur springs.

It is intensely acid. *Composition,* Sulphur teroxide (SO_3) 81·6, water 18·4=100, it being chemically *hydrogen sulphate.* Occurs in the waters of Rio Vinagre, South America; also in Java, and at Lake de Taal on Luzon, in the East Indies; in Genesee Co., N. Y.; and at Tuscarora, St. Davids, and elsewhere, Canada West.

Sulphurous acid, or sulphur dioxide (SO_2), is produced when sulphur burns, and causes the odor perceived during the combustion. It is common about active volcanoes. It destroys life and extinguishes combustion. *Composition,* Sulphur 50·00, oxygen 50·00.

Native Tellurium.

Hexagonal; $R \wedge R = 86° 57'$. Occurs sometimes in six-sided prisms with perfect *lateral* cleavage; but is commonly granular massive. Color and streak tin-white. Brittle. H.=2–2·5. G.=6·1–6·3.

Sometimes contains a little iron, and also a trace of gold. In an open tube, B.B. yields a white inodorous sublimate, which may be fused to colorless transparent drops; and on charcoal fuses and volatilizes, tinging the flame green, and covering the charcoal with white tellurium dioxide.

Obs. Occurs in Hungary and Transylvania; also, Boulder Co., Colorado, at the Red Cloud Mine; in Magnolia District at the Keystone, Dun River, and other mines; in the Ballerat District at Smuggler Mine; in Central District at the John Jay Mine, where masses of 25 pounds weight are reported to have been found.

Tellurium is also a constituent of ores of silver and lead (pp. 118, 149), and these are the chief sources of the metal.

Tellurite or *Tellurous acid,* TeO_2, occurs at the Keystone, Smuggler, and John Jay Mines; especially the last, where it is in minute white or yellowish crystals having one eminent cleavage.

Molybdenite.—Molybdenum Sulphide.

Hexagonal. In hexagonal plates, or masses, thin foliated, like graphite, and resembling that mineral. H.= 1–1·5. G.= 4·45–4·8. Color pure lead-gray; streak the same, slightly inclined to green. Thin laminæ very flexible; not elastic; leaves a trace on paper, like graphite, but its color is slightly different, being bluish-gray.

Composition. Mo S_2=Sulphur 41·0, molybdenum 59·0=100. B.B. infusible, but when heated on charcoal, sulphur fumes are given off, which are deposited on the coal. Dissolves in nitric acid, excepting a gray residue.

Diff. Resembles graphite, but differs in its paler color and streak, and also in giving fumes of sulphur when heated, as well as by its solubility in nitric acid.

Obs. Occurs in granite, gneiss, mica schist, and allied rocks; also in granular limestone. It is found in Sweden, at Arendal in Norway, in Saxony, Bohemia, at Caldbeck Fell in Cumberland, and in the Cornish mines.

In the United States it occurs in Maine at Blue Hill Bay, Camdage Farm, Brunswick, and Bowdoinham; in New Hampshire at Westmoreland, Landaff, and Franconia; in Massachusetts at Shutesbury and Brimfield; in Connecticut at Haddam and Saybrook; in New York near Warwick; in New Jersey near the Franklin Furnace.

Molybdenum does not occur native. An oxide is occasionally found in yellow incrustations on molybdenite, as a result of its alteration. It occurs, combined with lead, as a molybdate (page 151), and this is the only native salt containing it. The name molybdenum is from the Greek *molubdaina,* meaning mass of lead, and alludes to the resemblance of molybdenite to graphite.

TUNGSTITE, or Tungstic ochre. A yellow powder or incrustation occurring with wolfram, and a result of its decomposition. Occasionally observed at Lane's Mine, Monroe, Conn.

Besides this oxide there are the native compounds, iron tungstate or wolfram (p. 183), lead tungstate (p. 151), and calcium tungstate. Tungsten also occurs sparingly in some ores of columbium, as in certain varieties of the minerals pyrochlore, columbite, and yttro-columbite.

II. BORON GROUP.

In Boron, as in the Sulphur group, the most prominent oxide is a teroxide.

Sassolite.—Boracic Acid. Sassolin.

Occurs in small scales, white or yellowish. Feel smooth and unctuous. Taste acidulous and a little saline and bitter.

G.=1·48. *Composition*, $H_6O_6Bo_2$ = Boron teroxide 56·4, water 43·6. It is strictly *hydrogen borate*. Fuses easily in the flame of a candle, tinging the flame at first green.

Found at the crater of Vulcano, and also at Sasso in Italy, whence it was called *Sassolin*. The hot vapors of the lagoons of Tuscany afford it in large quantities. The vapors are made to pass through water, which condenses them; and the water is then evaporated by the steam of the springs, and boracic acid obtained in large crystalline flakes. It still requires purification, as the best thus procured contains but 50 per cent. of the pure acid. Occurs also in the waters of Lick Springs, Tehama Co., and Borax Lake, Lake Co., California, where it was first observed, through their evaporation, by Dr. J. A. Veatch, in 1856. It has since been obtained from the waters of Mono, Owens, and other lakes. It exists sparingly in the waters of the ocean. But in all these waters, it is probably in combination.

Boron occurs usually in the condition of magnesium, calcium, and sodium borates (pp. 206, 212, 227); and rarely as an iron borate (p. 182), or ammonium borate (p. 231). It also occurs in the silicates, tourmaline, danburite, axinite, and datolite, in which it is easily detected by the blowpipe reaction (p. 87).

III. THE ARSENIC GROUP.

The elements of the Arsenic group occurring among minerals are, arsenic, antimony, bismuth, phosphorus, nitrogen, vanadium, tantalum, columbium. Of these arsenic, antimony, and bismuth occur native, and as sulphides; also, in combination with other metals, constituting arsenides, antimonides, bismutides; and, along with sulphur also, making sulpharsenites, sulphantimonites, sulphbismutites. In addition, they all, excepting bismuth, enter into the constitution of a series of native ternary oxygen compounds or salts, called severally, arsenates, antimonates, phosphates, nitrates, vanadates, tantalates, columbates.

The chief oxide has the general formula R_2O_5.

Native Arsenic.

Rhombohedral. $R \wedge R = 85° 41'$. Cleavage basal, imperfect. Also massive, columnar, or granular.

Color and streak tin-white, but usually dark grayish from tarnish. Brittle. H. = 3·5. G. = 5·65–5·95.

B.B. volatilizes very readily before fusing, with the odor of garlic; also burns with a pale bluish flame when heated just below redness.

Obs. Occurs with silver and lead ores. It is found in considerable quantities at the silver mines of Freiberg and Schneeberg; also in Bohemia, the Hartz, at Kapnik in Upper Hungary, in Siberia in large masses, and elsewhere.

In the United States it has been observed at Haverhill and Jackson, N. H., and at Greenwood, Me.

Orpiment.—Yellow Arsenic Sulphide.

Trimetric. Cleavage highly perfect in one direction. In foliated masses, and sometimes in prismatic crystals. Color and streak fine yellow. Lustre brilliant pearly, or metallic pearly, on the face of cleavage. Subtransparent to translucent; sectile. H. = 1·5–2. G. = 3·4–3·5.

Composition. As_2S_3 = Sulphur 39·0, arsenic 61·0. Wholly evaporates before the blowpipe with an alliaceous odor, and on charcoal burns with a blue flame.

From Hungary, Koordistan in Turkey in Asia, China, and South America. Occurs at Edenville, N. Y., as a yellow powder, resulting from the decompositon of arsenical iron.

Realgar is another arsenic sulphide. It has a fine clear red color, aurora red to orange, and occurs transparent or translucent; H. = 1·5–2; G. = 3·35–3·65; *Composition*, AsS = Sulphur 29·9, arsenic 70·1. Like the preceding before the blowpipe. From Hungary, Bohemia, Saxony, the Hartz, Switzerland, and Koordistan in Asiatic Turkey. It has been observed in the lavas of Vesuvius.

Realgar is one of the ingredients of *white Indian fire*, often used as a signal light. Orpiment is a coloring ingredient in the pigment called *king's yellow*, in which it is mixed with arsenious acid.

Arsenolite.—White Arsenic.

Isometric. In minute capillary crystals, and botryoidal or stalactitic. Color white. Soluble; taste astringent, sweetish. H. = 1·5. G. = 3·7.

Composition. As_2O_3 = Arsenic 75·8, oxygen 24·2 = 100.

This is the same compound with the common *arsenic* of the shops. It is found but sparingly native, accompanying ores of silver, lead, and arsenic in the Hartz, Bohemia, and elsewhere. It is a well-known poison.

Claudetite **is the same compound in trimetric crystallizations, from Portugal.**

General Remarks.—Arsenic is obtained for commerce chiefly from arsenopyrite (or mispickel), an iron sulph-arsenide, and from the nickel and cobalt arsenides, by first roasting off the sulphur, and then condensing the arsenic, in the state of As_2O_3 ("arsenous acid") in large chambers. To obtain the material pure it is usually sublimed again in iron pots, in the upper part of which (artificially kept cool) it is condensed, mostly in a half-fused vitreous condition. To reduce the oxide to the metallic state it is heated with charcoal. In Devon and Cornwall the arsenical ores occur with the tin ore, and a large amount of white arsenic is made. The metal arsenic forms a small part of some alloys; the most important is that with lead for shot making.

Native Antimony.

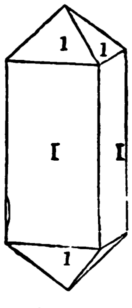
Rhombohedral; $R \wedge R = 87° 35'$. Usually massive, with a very distinct lamellar structure; sometimes granular. Color and streak tin-white. Brittle. H.=3–3·5. G.=6·6–6·75.

Composition. Pure antimony, often with a little silver, iron, or arsenic. B.B. on charcoal fuses easily and passes off in white fumes.

Obs. Occurs in veins of silver and other ores in Dauphiny, Bohemia, Sweden, the Hartz, and Mexico.

Stibnite.—Gray Antimony. Antimony Sulphide.

Trimetric. In right rhombic prisms, with striated lateral faces; $I \wedge I = 90° 45'$. Cleavage in the direction of the shorter diagonal, highly perfect. Commonly divergent columnar or fibrous. Sometimes massive granular.



Color and streak lead-gray; liable to tarnish. Lustre shining. Brittle; but thin laminæ a little flexible. Somewhat sectile. H.=2. G.=4·5–4·62.

Composition. Sb_2S_3=Sulphur 28·2, antimony 71·8. Fuses readily in the flame of a candle. B.B. on charcoal it is absorbed, giving off white fumes and a sulphur odor.

Diff. Distinguished by its extreme fusibility and its vaporizing before the blowpipe.

Obs. Stibnite occurs in veins with ores of silver, lead, zinc, or iron, and is often associated with barite, spathic iron, or quartz. It occurs at Felsöbanya and Schemnitz in Hungary; at Wolfsberg in the Hartz; at Bräunsdorf near Freiberg; in Auvergne, Cornwall, Spain, and Borneo.

In the United States, it has been found sparingly at Carmel, Me., Lyme, N. H., and at "Soldier's Delight," Md., in the Humboldt mining region, and in the mines of Aurora, Esmeralda County, Nevada.

This ore affords much of the antimony of commerce. By simple fusion, the crude antimony of the shops is obtained, from which pure antimony and its pharmaceutical preparations are made.

Allemontite is an arsenical antimony, Sb_2As_3, from Allemont, and also from Bohemia and the Hartz.

Valentinite. White antimony in white, grayish, or reddish rectangular crystals, with perfect cleavage, affording a rhombic prism of 136° 58′. Also in tabular masses, and columnar and granular. H.=2·5–3. G.=5·57. Lustre adamantine to pearly. *Composition,* Sb_2O_3 =Oxygen 16·44, antimony 83·56=100.

Senarmontite is the same compound in isometric forms.

Kermesite or *red antimony* is an antimony oxide and sulphide, in red tufts of capillary crystals. Lustre adamantine. From Hungary, Dauphiny, Saxony, and the Hartz.

Cervantite. An oxide of antimony, Sb_2O_4, resulting from the decomposition of stibnite.

Livingstonite. Like stibnite, but contains 14 per cent. of mercury and has a *red streak.* From Mexico.

Native Bismuth.

Rhombohedral; $R \wedge R = 87° 40'$. Cleavage rhombohedral, perfect. Generally massive, with distinct cleavage; sometimes granular.

Color and streak silver white, with a slight tinge of red. Subject to tarnish. Brittle when cold, but somewhat malleable when heated. H.=2–2·5. G.=9·7–9·8. Fuses at a temperature of 476° F.

Composition. Pure bismuth, with sometimes a trace of arsenic, sulphur or tellurium. B.B. on charcoal vaporizes, and leaves a yellow coating on the coal, paler on cooling.

Obs. Native Bismuth is abundant with ores of silver and cobalt in Saxony and Bohemia, and occurs also in Cornwall and Cumberland, England. At Schneeberg, it forms arborescent delineations in brown jasper. Occurs also in Norway, Sweden, Chili and Bolivia; also at the Balhannah mine, in S. Australia, with copper ore and gold.

In the United States, it has been found at Lane's and Booth's mine, Monroe, where it occurs with tungsten, galenite and pyrite; also at Brewer's mine, in Chesterfield district, South Carolina; and in Colorado.

Bismuthinite. A bismuth sulphide, Bi_2S_3, in acicular crystals of a lead-gray color.

Guanajuatite. A bismuth selenide, from Guanajuato, Mexico, called also *frenzelite.* *Silaonite* is a selenide from the same locality, of a lead-gray color.

Bismite. Bismuth ochre, an impure oxide, grayish, to greenish and yellowish white, and massive or earthy, found with native bismuth.

Tetradymite.—Bismuth Telluride.

Hexagonal; $R \wedge R = 81° 2'$. Crystals often tubular, with a very perfect basal cleavage. Also massive, and foliated or granular. Laminæ flexible, and soil paper. Lustre splendent metallic. Color pale steel-gray, a little sectile. H. $=1·5$—2. G. $=7·2$—$7·9$.

Composition. Consists of bismuth and tellurium, with sometimes sulphur and selenium, affording for the most part the formula $Bi_2(Te, S)_3$. A variety from Dahlonega, Georgia, gave Tellurium 48·1, bismuth $51·9 = Bi_2Te_3$; G. $=7·642$. *Joseite* is a bismuth telluride from Brazil, in which half the bismuth is replaced by sulphur; and *Wehrlite* is another containing sulphur, from Deutsch Pilsen, Hungary, having $G = 8·44$.

Obs. Found with gold in Virginia, North Carolina, and Georgia; Highland, Montana Territory; Red Cloud Mine, Colorado; Montgomery Mine, Arizona.

General Remarks. — The metal *bismuth* is obtained mostly from native bismuth. Besides the above ores, there are also others in which the metal is combined with silver, lead, and cobalt (pp. 116, 166); and a *carbonate of bismuth,* which occurs rarely in connection with native bismuth or the ores of the metal, as a result of oxidation; also a *silicate.*

IV. CARBON GROUP.

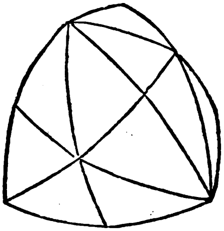
The Carbon group in chemistry comprises carbon and silicon, in which the formula for the most prominent oxide is $R\,O_2$. Only carbon occurs native.

Carbon occurs crystallized in the diamond and graphite; as oxides, in carbon oxide, and carbon dioxide (ordinarily called carbonic acid); combined with hydrogen, or hydrogen and oxygen, in bitumen, mineral oils, amber, and a number of native mineral resins, and mineral wax; and as the chief constituent of mineral coal, in which it is combined with more or less of hydrogen and oxygen and usually some nitrogen.

Diamond.

Isometric. In octahedrons, dodecahedrons and more complex forms. Faces often curved, as in the figures. Cleavage octahedral; perfect.

1.



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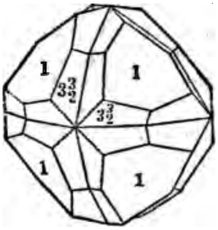

Color white, or colorless; also yellowish, red, orange, green, blue, brown or black. Lustre adamantine. Transparent; translucent when dark-colored. H.=10. G.=3·48—3·55.

Composition. Pure carbon. It burns and is consumed at a high temperature, producing carbonic acid gas. Exhibits vitreous electricity when rubbed. Some specimens exposed to the sun for a while, give out light when carried to a dark place. Strongly refracts and disperses light.

Diff. Diamonds are distinguished by their superior hardness; their brilliant reflection of light and adamantine lustre, their vitreous electricity when rubbed, which is not afforded by other gems unless they are polished; and, by the practiced ear, by means of the sound when rubbed together.

Obs. The coarse diamonds, unfit for jewelry, are called *bort*, and the kind in black pebbles, or masses, from Brazil, *carbonado.* The latter occur sometimes in pieces 1,000 carats in weight; they have G.=3 to 3·42. Another kind is much like anthracite, G.=1·66, although as hard as diamond crystals; it is in globules or mammillary masses, often partly made up of concentric layers.

Diamonds occur in India, in the district between Golconda and Masulipatam, and near Parma, in Bundelcund, where some of the largest have been found; also on the Mahanuddy, in Ellore. In Borneo, they are obtained on the west side of the Ratoos Mountain, with gold and platina. The Brazilian mines were first discovered in 1728, in the district of Serra do Frio, to the north of Rio de Janeiro ; the most celebrated are on the river Jequitinhonha, which is called the Diamond River, and the Rio Pardo ; seventy to seventy-five thousand carats are exported annually from these regions. In the Urals of Russia they had not been detected till July, 1829, when Humboldt and Rose were on their journey to Siberia. The river Gunil, in the province of Constantine, in Africa, is reported to have afforded some diamonds.

In South Africa, where they were first discovered in 1867, they occur in the gravel of the Vaal River, and in the Orange River country. The value of the diamonds obtained up to November, 1875, has been estimated as exceeding 60,000,000 of dollars.

In the United States, the diamond has been met with in Rutherford County, North Carolina; Hall County, Georgia; also Franklin County, North Carolina ; in Manchester, opposite Richmond, Virginia ; also in Cherokee Ravine, Butte County, Forest Hill in El Dorado County (one weighing nearly 5·62 grains), Fiddletown in Amador County, and in Nevada County, California; and on the coast of Southern Oregon. It has been reported from Idaho.

The original rock in Brazil appears to be either a kind of laminated granular quartz, called *itacolumyte ;* or a ferruginous quartzose conglomerate. The itacolumyte occurs in the Urals, and diamonds have been found in it ; and it is also abundant in Georgia and North Carolina. In India, the rock is a quartzose conglomerate. The origin of the diamond has been a subject of speculation, and it is the prevalent opinion that the carbon, like that of coal and mineral oil, is of vegetable or animal origin. Some crystals have been found with black uncrystallized particles or seams within, looking like coal ; and this fact has been supposed to indicate such an origin.

Diamonds, with few exceptions, are obtained from alluvial washings. In Brazil, the sands and pebbles of the diamond rivers and brooks (the waters of which are drawn off in the dry season to allow of the work) are collected and washed under a shed, by a stream of water passing through a succession of boxes. A washer stands by each box, and inspectors are stationed at intervals.

Diamonds are valued according to their color, transparency and size. The rose diamond is more valuable than the pure white, owing to the great beauty of its color and its rarity. The green diamond is much esteemed on account of its color. The blue is prized only for its rarity, as the color is seldom pure. The black diamond, which is uncommonly rare and without beauty, is highly prized by collectors. The brown, gray and yellow varieties are of much less value than the pure white or limpid diamond.

The largest diamond of which we have any knowledge is mentioned by Tavernier, as in the possession of the Great Mogul. It weighed originally 900 carats, or 2,769·3 grains, but was reduced by cutting to 861 grains. It has the form and size of half of a hen's egg. It was found in 1550, in the mine of Colone. The diamond which formed the eye of a Braminican idol, and was purchased by the Empress Catherine II. of Russia from a French grenadier who had stolen it, weighs 194¾ carats, and is as large as a pigeon's egg. The Austrian crown has a diamond weighing 139½ carats. The Pitt or Regent diamond is of less size, it weighing but 136·25 carats, or 419¼ grains; but on account of its unblemished transparency and color, it is considered the most splendid of Indian diamonds. It was sold to the Duke of Orleans by Mr. Pitt, an English gentleman, who was governor of Bencolen, in Sumatra, for £130,000. It is cut in the form of a brilliant, and is estimated at £125,000. The Rajah of Mattan has in his possession a diamond from Borneo, weighing 367 carats. The Koh-i-noor, on its arrival in England, weighed 186·016 carats.* It is said by Tavernier to have originally weighed 787½ carats. It has since been recut and reduced one-third in weight.

In the Dresden Treasury there is an emerald green diamond, weighing 31¼ carats. The *Hope* diamond, weighing 44⅛ carats, has a beautiful sapphire-blue color.

The diamonds of Brazil are seldom large. Maure mentions one of 120 carats, but they rarely exceed 18 or 20. One weighing 254½ carats, called the "*Star of the South*," was found in 1854.

Of South African diamonds, the "Schreiner" weighed,

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* A carat is a conventional weight, and is divided into 4 grains, which are a little lighter than 4 grains troy; 74 1-16 carat grains are equal to 72 troy grains. The term *carat* is derived from the name of a bean in Africa, which, in a dried state, has long been used in that country for weighing gold. These beans were early carried to India, and were employed there for weighing diamonds.

in its rough state, 308 carats; and the "Stewart," which has a light straw color, 288·35 carats. The diamonds of South Africa are mostly "off color;" about 10 per cent. are of first quality; 15, 2d; 20, 3d; and 55 per cent. are *bort* (W. J. Morton). The "Star of South Africa," of pure water, weighed 83·5 carats. Some crystals crack to pieces after being exposed to the air awhile.

The diamond is cut by taking advantage of its cleavage, and also by abrasion with its own powder. The flaws are sometimes removed by cleaving it. Afterwards the crystal is fixed to the end of a stick of soft solder when the solder is in a half-melted state, leaving the part projecting which is to be cut. A circular plate of soft iron is then charged with the powder of the diamond, and this, by its revolution, grinds and polishes the stone. By changing the position, other facets are added in succession till the required form is obtained. Diamonds were first cut in Europe, in 1456, by Louis Berquen, a citizen of Bruges; but in China and India, the art of cutting appears to have been known at a very early period.

By the above process, diamonds are cut into *brilliant, rose* and *table* diamonds. The brilliant has a *crown* or upper part, consisting of a large central eight-sided facet, and a series of facets around it; and a *collet*, or lower part, of pyramidal shapes, consisting of a series of facets, with a maller series near the base of the crown. The depth of a brilliant is nearly equal to its breadth, and it therefore requires a thick stone. Thinner stones, in proportion to the breadth, are cut into rose and table diamonds. The surface of the *rose* diamond consists of a central eight-sided facet of small size, eight triangles, one corresponding to each side of the table, eight trapeziums next, and then a series of sixteen triangles. The collet side consists of a minute central octagon, surrounded by eight trapeziums, corresponding to the angles of the octagon, each of which trapeziums is subdivided by a salient angle into one irregular pentagon and two triangles. The *table* is the least beautiful mode of cutting, and is used for such fragments as are quite thin in proportion to the breadth. It has a square central facet, surrounded by two or more series of four-sided facets, corresponding to the sides of the square.

Diamonds have also been cut with figures upon them. As early as 1500, Charadossa cut the figure of one of the Fathers of the church on a diamond, for Pope Julius II.

Diamonds are employed for cutting glass; and for this purpose only the natural edges of crystals can be used, and those with curved faces are much the best. Diamond dust is used to charge metal plates of various kinds for jewelers, lapidaries and others. Those diamonds that are unfit for working, are sold for various purposes, under the name of *bort.* Drills are made of small splinters of bort, and used for drilling other gems, and also for piercing holes in artificial teeth and vitreous substances generally; and, others of iron set with a few diamonds, for drilling rocks.

Graphite.—Plumbago.

Hexagonal. Sometimes in six-sided prisms or tables with a transversely foliated structure. Usually foliated, and massive; also granular and compact.

Lustre metallic, and color iron-black to dark steel-gray. Thin laminæ flexible. H.=1–2. G.=2·25–2·27. Soils paper, and feels greasy.

Composition. Commonly 95 to 99 per cent. of carbon. B.B. infusible, both alone and with reagents; not acted upon by acids.

Diff. Resembles molybdenite, but differs in being unaffected by the blowpipe and acids. The same characters distinguish the granular varieties from any metallic ores they resemble.

Obs. Graphite (called also *black lead*) is found in crystalline rocks, especially in gneiss, mica schist and granular limestone; also in granite and argillyte. Its principal English locality at Borrowdale, in Cumberland, is now nearly exhausted.

In the United States graphite occurs in large masses in veins in gneiss at Sturbridge, Mass. It is also found in North Brookfield, Brimfield and Hinsdale, Mass.; abundant at Roger's Rock, near Ticonderoga; near Fishkill Landing in Dutchess County; at Rossie, in St. Lawrence County, and near Amity, in Orange County, N. Y.; at Greenville, N. C.; in Cornwall, near the Housatonic, and in Ashford, Ct.; near Attleboro, in Bucks County, Penn.; in Brandon, Vermont; in Wake, North Carolina; on Tyger River, and at Spartanburg, near the Cowpens Furnace, South Carolina; also abundantly and of excellent quality in Canada, in Buckingham, Fitzroy and Grenville.

For the manufacture of the best pencils the granular graphite was thought necessary, and hence the former great value of the Borrowdale mine, where the texture was peculiarly fine and firm. But now the graphite is ground up, and then compressed under heavy pressure, and thus the fine texture and firmness required may be obtained with any pure graphite. At Sturbridge, Mass., it is rather coarsely granular and foliated, and has been extensively worked. The mines of Ticonderoga and Fishkill Landing, N. Y.; of Brandon, Vt.; and of Wake, North Carolina, are also worked; and that of Ashford, Ct., formerly afforded a large amount of graphite, though now the works are suspended.

Graphite is extensively employed for diminishing the friction of machinery; also for the manufacture of crucibles and furnaces; and as a wash for giving a gloss to iron stoves and railings. For crucibles it is mixed with half its weight of clay.

Carbonic Acid.

Carbonic acid—carbon dioxide of existing chemistry—is the gas that gives briskness to the Saratoga and many other mineral waters, and to artificial soda water. Its taste is slightly pungent. It extinguishes combustion and destroys life.

Composition. $C\,O_2$=Oxygen 72·35, carbon 27·65=100.

This gas is contained in the atmosphere, constituting about 4 parts, by volume, in 10,000 parts; and it is present in minute quantities in the waters of the ocean and land. It is given out by animals in respiration, and is one of the results of animal and vegetable decomposition; and from this source the waters derive much of their carbonic acid. This gas is the *choke-damp* of mines, where it is often the occasion of the destruction of life. It is often present also in wells.

Carbon dioxide (or carbonic acid) is given out by limestone (or calcium carbonate) when it is heated; and quicklime is limestone from which $C\,O_2$ has been expelled by heat, a process carried on usually in a *limekiln.* It is also driven from limestone by the action of sulphuric acid, with the formation of gypsum (a hydrous calcium sulphate), or anhydrite (an anhydrous calcium sulphate). These processes are often carried on in volcanoes, and hence carbonic acid gas is common in some volcanic regions. The *Grotto del Cane* (Dog Cave) at the Solfatara near Naples, is a small cavern filled to the level of the entrance with this gas. It is a common amusement for the traveler to witness its effect upon a dog kept for that purpose. He is held in the gas awhile and is then thrown out apparently lifeless; in a few minutes he recovers himself, picks up his reward, a bit of meat, and runs off as lively as ever. If continued in the carbonic acid gas a short time longer, life would have been extinct.

Carbonic acid, under high pressure, becomes a liquid, and, with pressure and cold, a white snow-like solid. In the liquid state it is often found in microscopic globules in the interior of crystallized quartz, topaz, and some other minerals; and when this is true, calcite (calcium carbonate) is often present in the same or an adjoining rock.

Besides the calcium carbonate in nature, there are also carbonates of ammonium, sodium, barium, strontium, magnesium, iron, manganese, zinc, copper, lead, nickel, cobalt, bismuth, uranium, cerium, and lanthanum.

II. MINERALS CONSISTING OF THE BASIC ELEMENTS WITH OR WITHOUT ACIDIC—THE SILICATES EXCLUDED.

I. GOLD.

Gold occurs mostly native, being either pure, or alloyed with silver and other metals. It is occasionally found mineralized by tellurium, making part of the valuable minerals Sylvanite, Nagyagite and Petzite. It occurs often disseminated through pyrite and galenite in auriferous regions, rendering these minerals valuable sources of gold.

Native Gold.

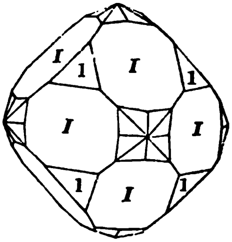
Isometric. In octahedrons, dodecahedrons; without cleavage. Also in arborescent forms, consisting of strings of crystals, filiform, reticulated, in grains, thin laminæ and masses.

Color various shades of gold-yellow, becoming pale from alloy with silver; occasionally nearly silver-white from the silver present. Eminently ductile and malleable. H. = 2·5–3. G. = 12–20, varying according to the metals alloyed with the gold. Fuses at 2,016° F. (1,102° C.)

Composition. Native gold usually contains silver, and in very various proportions; and the color becomes paler with the increase of silver. The finest native gold from Russia yielded gold 98·96, silver 0·16, copper 0·35, iron 0·05; G.=19·099. A gold from Marmato afforded only 73·45 per cent. of gold, with 26·48 per cent. of silver; G.=12·666. This last is in the proportion of 3 of gold to 2 of silver. The following proportions also have been observed: 3½ to 2; 5 to 2; 3 to 1; 4 to 1, and this the most common; 6 to 1 is also of frequent occurrence. Average of California native gold is 88 per cent. gold, and the range mostly between 87 and 89; the range of the Canadian, mostly between 85 and 90; of Australian, between 90 and 96 per cent., and the average 93½. The Chilian gold afforded Domeyko 84 to 96 per cent. of gold, and 15 to 3 per cent. of silver. The more argentiferous gold has been called *Electrum;* the atomic proportion of 1 : 1 between the gold and silver corresponds to 35·5 per cent. of silver, and that of 2 : 1, to 21·6 per cent.

1.

2.



Copper is occasionally found in alloy with gold, and sometimes also iron, bismuth, palladium and rhodium. A *rhodium-gold* from Mexico gave the specific gravity 15·5–16·8, and contained 34 to 43 per cent. of rhodium. A bismuth gold has been called *Maldonite.*

Diff. Iron and copper pyrites are often mistaken for gold by those inexperienced in ores; but these are brittle minerals, while gold may be cut in slices, and flattens under a hammer. Pyrite is too hard to yield at all to a knife, and copper pyrites affords a dull greenish powder. Moreover pyrite gives off sulphur when strongly heated, while gold melts without odor.

Obs. Native gold is mostly confined to quartz, intersecting in veins, or interlaminated with, subcrystalline slaty or schistose rocks, especially hydromica and chloritic slates. It occurs sparingly in similar or other veins in granite, gneiss, or mica slate. It has also been found in traces, according to J. J. Stevenson, in the trachytes of Colorado, and in Silurian and Carboniferous quartzytes.

The quartz intersects the slaty rocks in veins and lies in thick seams between their layers. It is frequently cellular for a considerable distance from the surface owing to the alteration and removal of pyrite, galena, or other metallic ores that may be accompaniments of the gold, and the cavities are usually rusty with oxide of iron, and sometimes contain particles of sulphur left by the decomposing pyrite, and also strings or laminæ of gold. The rock in this cavernous state is rather easily quarried out; but deep below, where the minerals are not removed by decomposition, mining is far more difficult.

Pyrite itself is nearly as hard as quartz, when unaltered, and readily strikes fire with a steel. This pyrite is often very abundant, and contains throughout it considerable gold; but the gold is so finely distributed, that little of it can be removed by the ordinary process of crushing and amalgamation; nature's way consists in *decomposing* the pyrite and thereby making it drop its load. The galenite of a gold region is also usually auriferous.

Gold sometimes occurs in the slate rocks adjoining the veins, though mostly confined to the latter. Auriferous quartz often contains no gold visible to the naked eye.

But while quartz veins are to a large extent the actual repositories of the gold in its native state, a very large part of the gold derived from auriferous regions has come from the sand and gravel beds, in which it occurs in flattened grains, and sometimes in lumps and nuggets. By different methods—erosion by running waters, movements of glaciers, natural decomposition, and other disintegrating action—the gold-bearing rocks have been extensively reduced to earth and stones, and this loose material has been distributed along the river courses, making vast alluvial or diluvial gravelly formations. From these gravels the gold is obtained by simple washing, thus taking advantage of the high specific gravity of gold. Streams are carried in aqueducts and thrown in great jets against the gravel bluffs to reduce the material to loose earth and prepare it for further washing by the same water in sluices arranged for the purpose.

The minerals most common in gold regions are platinum, iridosmine, magnetite, pyrite, galenite, ilmenite, chalcopyrite, blende, tetradymite, zircon, rutile, barite; also in some cases wolfram, scheelite, brookite, monazite and diamond. Platinum and iridosmine accompany the gold of the Urals, Brazil and California; and diamonds are found in the gold region of Brazil, and occasionally in the Urals and United States.

Gold is widely distributed over the globe. In AMERICA, it occurs in Brazil (where formerly a greater part of that used was obtained) along the chain of mountains which runs nearly parallel with the coast, especially near Villa Rica, and in the province of Minas Geraes; in New Granada, at Antioquia, Choco and Giron; in Chili; sparingly in Peru and Mexico; in Arizona; in the Coast Range, and, much more abundantly, in the Sierra Nevada, California; in Oregon, British Columbia and Alaska; in New Mexico, Colorado, and Wyoming, and other parts of the Rocky Mountain region; in the Appalachians from Virginia to Georgia, a region that formerly produced annually nearly a million of dollars; very sparingly in Vermont, New Hampshire, and other New England States; in Nova Scotia; in Beauce County, Canada; also, north of Lake Superior; and in the gravel of Illinois and Indiana.

In EUROPE, it occurs sparingly in Cornwall and Devon, England; North Wales, Scotland, and Ireland, formerly in the County of Wicklow, where a nugget of 22 ounces was found; and in France, very sparingly in the Department of Isère; in the sands of the Rhine, the Reuss, and the Aar; in Tyrol and Salzburg; on the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the Valley of Aosta, Northern Piedmont, where nearly 6,000 ounces were obtained in 1867; more abundantly in Hungary, at Königsberg, Schemnitz and Felsobanya, and in Transylvania, at Kapnik, Vöröspatak and Offenbanya; in Spain, formerly worked in Asturias; in Sweden, at Edelfors.

In the Urals are valuable mines at Beresof, and other places on the eastern or Asiatic flank of this range, and the comparatively level portions of Siberia; also in the Altai Mountains. Also in the Cailas Mountains in Little Thibet sparingly in the rivers of Syria and other parts of Asia Minor; in Ceylon, China, Japan, Formosa, Java, Sumatra, Western Borneo, the Philippines, and New Guinea.

In AFRICA, at Kordofan, between Darfour and Abyssinia; also south of Sahara, in the western part of Africa, from the Senegal to Cape Palmas; also along the coast opposite Madagascar, between the 22d and 35th degrees south latitude, in the Transvaal Republic. Other regions are Tasmania, New Zealand, and New Caledonia.

General Remarks.—The most productive gold regions at the present time are those of Australia and California.

In Australia the richest mines are those of Victoria and New South Wales. Victoria yielded, in 1856, 3,000,000 ounces, and in 1875, 1,195,-250; Australia, in 1875, 227,000 ounces. The Australian gold was first made known to the world in 1851. The localities discovered were on Summer Hill Creek and the Lewis Pond River (near lat. 33° N., long. 149°-150′ E.), streams which run from the northern flank of the Coriobolas down to the river Macquarie, a river flowing westward and northward; it was soon afterward found on the Turon River, which rises in the Blue Mountains; and finally a region of country 1,000 miles in length, north and south, was proved to be auriferous (the country is a region of metamorphic rocks, granite and slates, and in many parts abounds in quartz veins.) Queensland and South Australia, and also Tasmania and New Zealand, afford some gold.

The first discovery of gold in California was made early in the spring of 1848, on the American Fork, a tributary to the Sacramento, near the mouth of which Sutter's establishment was situated. Soon Feather River, another affluent, 18 or 20 miles north, was also proved to abound in gold about its upper portions; and it was not long after before each stream in succession, north and south, along the western slope of the Sierra Nevada was found to flow over auriferous sands. The gold as now developed extends along that chain, through the whole length of the great north and south valley which holds the rivers and plains of the Sacramento and San Joaquin. It continues south nearly to the Tejon pass, in latitude 35°, and north beyond the Shasta Mountains to the Umpqua, and less productively into Oregon and Washington Territories, and in British Columbia. Gold also occurs in some places in the coast range of mountains. Even the very site of San Francisco has been found to contain traces. North of Shasta Mountain there are important mines on the Klamath and the Umpqua, and some of the best on the sea-shore between Gold Bluff, in 41° 30′ south of the Klamath (30 miles south of Crescent City) to the Umpqua. What once was Rogue River is now called Gold River.

In Colorado, gold mines occur in Gilpin County, and much less productively in Clear Creek, Park, Boulder, Lake, Summit, and Southern counties; and the yield in 1874 amounted to $2,102,487, of which $1,525,447 were from Gilpin County.

Nevada produced from the Comstock lode (see p. 123), in 1875, gold to the amount of about $11,740,000, and the rest of Nevada, $2,256,000.

making in all nearly $14,000,000; and in 1876, the Comstock lode yielded $18,000,000, and the rest of Nevada about $1,338,000.

The yield of the United States in gold in the years 1870 to 1876, is stated as follows in a note dated February 5, 1877, by J. J. Valentine, in Jones's "Report of the Silver Commission (1877)":

1870	$33,750,000
1871	34,398,000
1872	38,109,395
1873	39,206,558
1874	38,466,488
1875	39,968,194
1876	42,886,935

The amount, in 1874, from California is stated at $17,620,000; from Oregon, $609,000; Washington, $155,500; Idaho, $1,328,430; Montana, $2,850,000; Utah, $92,000; Arizona, $25,700; Colorado, $2,102,487; Mexico, $84,655; British Columbia, $1,636,200.

According to the Report of A. del Mar, in the "Report of the Silver Commission of 1877," the yield of gold from all America from 1492 to the year 1800, was $1,872,300,000. From 1800 to 1847 inclusive, 48 years, the yield from America, Europe, and Africa is stated at $120,200,000; and from 1848 to 1876 inclusive, 29 years, $3,381,500,000. The largest annual amount was produced in the year 1856, in which the yield was $147,600,000; and next to this, in 1859, with $144,900,000; as shown in the annexed table, giving the amounts in millions of dollars:

1848	67·5	1858	144·6	1868	109·7
1849	87·0	1859	144·9	1869	106·2
1850	93·2	1860	119·3	1870	106·9
1851	120·0	1861	113·8	1871	107·0
1852	193·7	1862	107·8	1872	99·6
1853	155·0	1863	107·0	1873	97·2
1854	127·0	1864	113·0	1874	90·8
1855	135·0	1865	130·7	1875	97·5
1856	147·6	1866	122·2	1876	90·0
1857	133·3	1867	114·0		

The total amount for these years is $3,381,500,000 The following table is taken from a Report to the British House of Commons in 1876 —the amount for the United States only being corrected:

	Russia.	United States.	Mexico and South America.	Australia.	Other Countries.	Total.
1850	$16,950,000	$27,500,000	....	....	....	....
1855	14,200,000	73,700,000	$5,000,000	$60,325,000	$2,500,000	$155,725,000
1860	15,265,000	46,000,000	4,500,000	52,500,000	2,500,000	120,765,000
1865	16,135,000	53,225,000	4,000,000	44,100,000	2,500,000	119,960,000
1870	22,070,000	33,750,000	2,500,000	29,150,000	2,500,000	89,970,000
1875	20,000,000	40,000,000	3,750,000	28,750,000	2,500,000	95,000,000

Masses of gold of considerable size have been found in North Carolina. The largest was discovered in Cabarrus County; it weighed 28 pounds avoirdupois ("steel-yard weight," equals 37 pounds troy), and was 8 or 9 inches long, by 4 or 5 broad, and about an inch thick. In Paraguay, pieces from 1 to 50 pounds weight were taken from a mass of rock which fell from one of the highest mountains.

The largest masses of gold yet discovered have been found in auriferous gravel. The "Blanch Barkley Nugget," found in South Australia, weighed 146 pounds, and only six ounces of it were gangue; and one still larger, the "Welcome Nugget," from Victoria, weighed 2,195 ounces, or nearly 183 pounds, and yielded £8,376 10*s.* 6*d.* sterling of gold. Two others from Victoria weighed 1,621, and 1,105 ounces. In Russia, a mass was found in 1842, near Miask, weighing 96 pounds troy; another of 27 pounds, and several of 16 pounds have been found in the Urals. The largest mass yet reported from California weighed 20 pounds. A remarkably beautiful mass, consisting of a congeries of crystals, weighing 201 ounces (value $4,000), was found in 1865, seven miles from Georgetown, in El Dorado County.

The origin of gold veins, or rather of the gold in the veins, is little understood. The rocks, as has been stated, are metamorphic slates that have been crystallized by heat; and they are the hydromica, chloritic, and argillaceous, that have been but imperfectly crystallized, rather than the mica schist and gneiss, which are well crystallized; and the veins of quartz which contain the gold, occupy fissures through the slates, and openings among the layers, which must have been made when the metamorphic changes or crystallization took place. It was a period, for each gold region, of long-continued heat (occupying, probably, a prolonged age), and also of vast upliftings and disturbances of the beds; for the beds are tilted at various angles, and the veins show where were the fractures of the layers, or the separations and gapings of the tortured strata. The heat appears not to have been of the intensity required for the better crystallization of the more perfectly crystalline schists. The quartz veins could not have been filled from below, by injection; they must have been filled either laterally, or from above. In all such conditions of upturning and metamorphism, the moisture present would have become intensely heated, and hence have had great dissolving and decomposing power; it would have taken up silica with alkalies from the rocks (as happens in all Geyser regions), along with whatever other mineral substances were capable of solution or removal; and the vapor, thus laden, would have filled all open spaces, there to make depositions of the silica and other ingredients it contained. These mineral ingredients would have been derived either from the rock adjoining the veins or opened spaces, or from depths below through ascending vapors. By one or both of these means, the quartz must have received its gold, pyrite, and ores of lead, copper and other materials—all having been carried into the open cavities at the same time with the silica or quartz. The pyrite of the vein is usually auriferous, showing that it was crystallized under the same circumstances that attended the depositing of the gold in strings, crystals, and grains; and the same is often true of the galena.

Calaverite is a bronze-yellow gold telluride. $AuTe_4$=Tellurium

55·5, gold 44·5=100, with a little silver, occurring massive at the Stanislaus Mine, California, and the Red Cloud Mine, Colorado, and also the Keystone and Mountain Lion mines, in the Magnolia District.

Krennerite is another gold telluride.

Sylvanite, called also *Graphic tellurium*, is a telluride of gold and silver, also containing sometimes antimony and more or less lead (see p. 118).

Nagyagite is a telluride of lead containing 9 to 13 per cent. of gold (see p. 149).

Petzite is a telluride of silver, allied to Hessite (p. 118), containing gold ; a specimen from Golden Rule Mine, Colorado, contained 25·60 per cent, according to Genth.

II. SILVER.

AgCl is valuable
[illegible]

Silver occurs native, and alloyed, or combined with gold ; also combined with sulphur, selenium, tellurium, arsenic, antimony, bismuth, chlorine, bromine, or iodine ; but never as an oxide, carbonate, sulphate, or phosphate.

Native Silver.

Isometric. In octahedrons and other forms. No cleavage apparent. Occurs often in filiform and arborescent shapes, the threads having a crystalline character ; also in laminæ, and massive.

Color and streak silver-white and shining. Often black externally from tarnish. Sectile. Malleable. H.=2·5–3. G.=10·1–11·1.

Composition. Native silver is usually an alloy of silver and copper, the latter ingredient often amounting to 10 per cent. It is also alloyed with gold, as mentioned under that metal. A *bismuth silver* from Copiapo, S. A., contained 16 per cent. of bismuth.

B.B. fuses easily to a silver-white globule. Dissolves in nitric acid, from which it is precipitated as white chloride on adding hydrochloric acid. A clean plate of copper immersed in the nitric solution becomes coated with silver.

Diff. Distinguished by being malleable ; from bismuth and other white native metals by affording no fumes before the blowpipe ; by affording a precipitate with hydrochloric acid which becomes black on exposure.

Obs. Native silver occurs in masses and string-like arborescences, penetrating the gangue, or its minerals, in various silver mines. It is also found mixed with native copper.

The mines of Norway, at Kongsberg, formerly afforded magnificent specimens of native silver, but they are now mostly under water. One specimen from this locality, at Copenhagen, weighs five hundred pounds; and two other masses have been found weighing 238 and 436 pounds. Other European localities are in Saxony, Bohemia, the Hartz, Hungary, Dauphiny. Peru and Mexico also afford native silver. A Mexican specimen from Batopilas, weighed when obtained 400 pounds; and one from Southern Peru (mines of Huantajaya) weighed over 8 cwt. Arizona is reported to have produced one mass weighing 2,700 pounds. In the United States, in the Lake Superior region, the silver generally penetrates the copper in masses and strings, and is very nearly pure, notwithstanding the copper about it. Large masses occur at the Idaho Silver Mine, called the Poor Man's Lode; and in strings it is occasionally found in the mines of Nevada, California, and Colorado.

Much of the galena of the world contains a very small percentage of silver; that of Monroe, Conn., yields nearly 3 per cent.

Native silver has also been observed near the Sing Sing state prison; at the Bridgewater copper mines, N. J.; and in handsome specimens at King's Mine, Davidson County, North Carolina.

Native Amalgam is a compound of silver and mercury. The compounds $AgHg$ = Silver 35·1, mercury 64·9, or $Ag_2 H_3$ = Silver 26·5, mercury 73·5, are included. Another from Chili having the formula $Ag_{12}Hg$ and containing 86·6 per cent. of silver has been called *Arquerite;* and still another $Ag_{18}Hg$, *Kongsbergite.*

Argentite.—Silver Glance. Sulphuret of Silver.

Isometric. In dodecahedrons more or less modified. Cleavage sometimes apparent parallel to the faces of the dodecahedron. Also reticulated and massive.

Lustre metallic. Color and streak blackish lead-gray; streak shining. Very sectile. H. = 2–2·5. G. = 7·19–7·4.

Composition. When pure, Ag_2S = Sulphur 12·9, silver 87·1. B.B. on charcoal in O.F. it intumesces, gives off the odor of sulphur, and finally affords a globule of silver.

Diff. Resembles some ores of copper and lead, and other ores of silver, but is distinguished by being easily cut, like lead, with a knife; and also by affording a globule of silver on charcoal, by heat alone. Its specific gravity is much higher than that of any copper ores.

Obs. This important ore of silver occurs in Europe principally at Annaberg, Joachimstahl, and other mines of the Erzgebirge; at Schemnitz, and Kremnitz, in Hungary, and at Freiberg in Saxony. It is a common ore at the Mexican silver mines, and also in the mines of South America. It occurs in Arizona, with chalcocite, at the Heintzelman Mine, and in Nevada.

A mass of "sulphuret of silver" is stated by Troost to have been found in Sparta, Tennessee.

Acanthite is a trimetric sulphide of silver, Ag_2S, from Joachimstahl; and *Daleminzite*, another, from near Freiberg.

Stromeyerite. A steel-gray sulphide of silver and copper, $Ag_2S + Cu_2S$ = Sulphur 15·7, silver 53·1, copper 31·2 = 100. G. = 6·26. B.B. it fuses and gives in the open tube an odor of sulphur; but a silver globule is not obtained except by cupellation with lead. From Peru, Silesia, Chili, Siberia, and Arizona.

Sternbergite. A sulphide of silver and iron containing 33 per cent. of silver. It is a highly foliated ore resembling graphite, and like it leaving a tracing on paper; the thin laminæ are flexible; color pinchbeck brown; streak black. From Joachimstahl and Johanngeorgenstadt.

Naumannite. A selenide of silver and lead in iron-black cubes and massive; G. = 8; contains 73 per cent. of silver. From the Hartz.

Hessite. A telluride of silver, Ag_2Te = Tellurium 37·2, silver 62·8 = 100. Color between lead-gray and steel-gray. Sectile. G. = 8·3—8·6. B.B. in the open tube, faint sublimate of tellurous acid; on charcoal with soda a silver globule. From the Altai; at Nagyag and Retzbanya; Coquimbo, Chili; Calaveras Co., Cal.; Red Cloud Mine, Colorado; Kearsarge Mine, Dry Canyon, Utah.

Petzite is a hessite with the silver replaced in part by gold. G. = 8·7–9·4. Between steel-gray and iron-black. Variety from Golden Rule Mine, afforded Genth Tellurium 32·68, silver 41·86, gold 25·60 = 100·14. Occurs at the same localities with hessite.

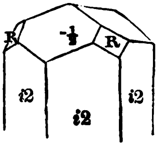
Tapalpite is a telluride of bismuth and silver from Mexico.

Sylvanite or *Graphic Tellurium.* A telluride of gold and silver $(Ag, Au)Te_3$ = (if Ag : Au = 1 : 1) Tellurium 55·8, gold 28·5, silver 15·7 = 100. Color and streak steel-gray to silver-white, and sometimes nearly brass-yellow. H. = 1·5-2. G. = 7·99–8·33. Called *graphic* because of a resemblance in the arrangement of the crystals to writing characters. From Transylvania; Calaveras Co., California; Red Cloud and Grand View Mines, Colorado.

Eucairite. A selenide of silver and copper, containing 42–45 per cent. of silver; color between silver-white and lead-gray; easily cut by the knife. From Sweden and Chili.

Dyscrasite, or *Antimonial Silver*, consists simply of silver and antimony (78 parts to 22=Ag_4Sb), and has nearly a tin-white color. G.=9·4–9·8. B.B. fumes of antimony pass off, leaving finally a globule of silver. From Wolfach, Wittichen, Andreasberg; also Allemont in Dauphiny; and Bolivia, S. A.

Pyrargyrite.—Ruby Silver. Dark Red Silver Ore.



Rhombohedral. $R \wedge R' = 108° \ 42$; $R \wedge i\text{-}2 = 129° \ 39'$. Cleavage parallel to R imperfect. Also massive. Black to dark cochineal-red, with the streak cochineal-red and lustre splendent metallic-adamantine. H.=2–2·5, G.=5·7–5·9.

Composition. Ag_3S_3Sb (=3 $Ag_2S+Sb_2S_3$) = Sulphur 17·7, antimony 22·5, silver 59·8=100.

B.B. fuses very easily; on charcoal a white deposit of antimony oxide is deposited, and with soda a globule of silver is obtained. In an open tube gives off sulphurous fumes that redden litmus paper.

Diff. Its red streak, and its reactions for antimony and silver, are distinctive.

Obs. Occurs at Andreasberg; also in Saxony, Hungary, Cornwall, Mexico, Chili; in Nevada at Washoe; abundant about Austin, Reese River; at Poor Man's Lode, Idaho.

Proustite, or *Light Red Silver Ore*, is a related ore containing arsenic in place of much or all of the antimony. *Composition*, Ag_3S_3As=Sulphur 19·4, arsenic 15·1, silver 65·5=100. G.=5·4–5·56.

B.B. gives a garlic odor.

Occurs with pyrargyrite at the above-mentioned localities.

Stephanite.—Brittle Silver Ore. Black Silver.

Trimetric. $I \wedge I$=115° 39′. No perfect cleavage. Often in compound crystals. Also massive. Streak and color iron-black. H.=2–2·5. G.=6·27.

Composition. Ag_5S_4Sb (= 5 $Ag_2S+Sb_2S_3$) = Sulphur 16·2, antimony 15·3, silver 68·5. B.B. it gives an odor of sulphur and also fumes of antimony, and yields a dark metallic globule, from which silver may be obtained by the addition of soda. Soluble in dilute nitric acid, and the solution indicates the presence of silver by silvering a plate of copper.

Obs. It occurs with other silver ores at Freiberg, Schneeberg, and Johanngeorgenstadt, in Saxony; also in Bohemia, and Hungary. It is an abundant ore in Chili, Peru, and Mexico, and also in Nevada, and at the Comstock Lode, and at Ophir, and Mexican mines, in the Reese River and Humboldt, and other regions; in Colorado and Idaho. It is sometimes called *black silver.*

Polybasite is near stephanite in color, specific gravity, and composition, but contains some arsenic and copper, with 64 to 72·2 per cent. of silver. The crystals are trimetric, and usually in tabular hexagonal prisms, without distinct cleavage. G.=6,214. From Freiberg, Przibram; Mexico and Chili; the Reese mines in Nevada, and Idaho.

Miargyrite is an antimonial silver sulphide, containing but 36·5 per cent. of silver, and having a *dark cherry-red streak,* though iron-black in color. B.B. on charcoal gives off fumes of antimony and an odor of sulphur; and in the oxidating flame, a globule is left which finally yields a button of pure silver.

Brongniardite occurs in regular octahedrons and massive, grayish-black in color, and contains about 25 per cent. of silver, with lead, antimony, and sulphur G.=5·95. From Mexico.

Polyargyrite also is isometric, having cubic cleavage, and is from Wolfach in Baden. It is near polybasite in composition$=12Ag_2S+Sb_2S_3$.

Freieslebenite is a monoclinic antimonial silver-and-lead sulphide, of a light steel-gray color, with G.=6–6·4. Contains 22 to 24 per cent. of silver. From Saxony, Transylvania, and Spain.

Pyrostilpnite is another monoclinic silver ore; its delicate crystals are grouped like stilbite and have a fire-red color. Contains 62·3 per cent. of silver. From Freiberg, Andreasberg, and Przibram.

Cerargyrite.—Horn Silver. Silver Chloride.

Isometric. In cubes, with no distinct cleavage. Also massive, and rarely columnar; often incrusting. Color gray, passing into green and blue; looks somewhat like horn or wax, and cuts like it. Lustre resinous, passing into adamantine. Streak shining. Translucent to nearly opaque.

Composition. $AgCl$=Chlorine 24·7, silver 75·3. Fuses in the flame of a candle, and emits acrid fumes. B.B. affords silver easily on charcoal. The surface of a plate of iron rubbed with it is silvered.

Obs. A very common ore and extensively worked in the mines of South America and Mexico, where it occurs with native silver; and also abundant in Nevada about Austin, Lander Co.; in Idaho at Poor Man's Lode; occurs also in Comstock Lode; and in Arizona; also at the mines of Saxony, Siberia, Norway, the Hartz, and Cornwall.

Bromyrite or *Bromic Silver.* Silver united with bromine. Ag Br= Bromine 42·6, silver 57·4=100. Occurs with the preceding in Mexico and Chili.

Embolite. A chlorobromide of silver, resembling the chloride or horn silver. Color asparagus to olive green. Contains 51 of chloride of silver, to 49 of bromide. This ore is not less common in Chili than the chloride. It has also been found in Chihuahua, Mexico.

Iodyrite. A silver iodide, Ag I=Iodine 54·0, silver 46·0=100. It has a bright yellow color. From Spain, Chili, Mexico, and the Cerro Colorado Mine in Arizona.

Tocornalite. A silver-and-mercury iodide from Chili.

General Remarks.—The chief sources of the silver of commerce are (1) *Native silver;* (2) the sulphide, *Argentite* (or vitreous silver), common in Mexico, and also in the Humboldt, Reese River mining districts; four species among the sulpharsenites and sulphantimonites, viz., (3) *Proustite* or the light red or ruby silver ore, and (4) *Pyrargyrite,* or dark red silver ore, both common in Chilian, Peruvian, and Mexican mines; (5) *Freieslebenite;* (6) *Argentiferous tetrahedrite,* which contains sometimes 10 to 30 per cent. of silver, abundant at some Humboldt County, Nevada, mines, at Colorado silver mines, and at various Chilian, Bolivian and Mexican mines, as well as in some silver mines of Europe; (7) *Stephanite* or brittle silver ore, common in Nevada, Colorado, and at the Washoe mines, Western Utah; (8) the chloride, called horn-silver or *Cerargyrite,* common in Chili, Mexico, Idaho; (9) the bromide and chlorobromide, *Bromyrite* and *Embolite,* common in Chili and Mexico, especially the latter, along with the rarer iodide; (10) *Argentiferous Galenite,* the lead ore, galenite, even when containing but 5 ounces of silver to the ton, being profitably worked for its silver. The other ores of silver mentioned beyond are seldom of great abundance. The most important of them are silver amalgam or *Arquerite,* common especially in Chili, and *Polybasite.*

Silver ores occur in rocks of various ages, in gneiss and allied rocks, in porphyry, trap, sandstone, limestone, and shales; and the sandstone and shales may be as recent as the Tertiary. The veins often intersect trachytic, porphyry, and other eruptive rocks, or the sedimentary formations in the vicinity of such rocks, and have owed their existence in many cases to the heat, fracturing, and vapors from below, attending the eruptions.

Silver ores are associated often with ores of lead, zinc, copper, cobalt, and antimony, and the usual gangue is calcite or quartz, with frequently fluor spar, pearl spar, or heavy spar.

The silver of South America is derived principally from the horn silvers, stephanite, ruby silver, vitreous silver ore, and native silver. Those of Mexico are of nearly the same character. Besides, there are earthy ores called *colorados,* and in Peru *pacos,* which are mostly earthy oxide of iron, with a little disseminated silver; they are found near the surface where the rock has undergone partial decomposition. The sulphides of lead, iron, and copper of the mining regions, generally contain silver, and are also worked.

In South America the Chilian mines are on the western slope of the Cordilleras, and are connected mostly with stratified deposits, of a shaly, sandstone, or conglomerate character, and their intersections with porphyries. The chlorides and native amalgams are found in regions more toward the coast, while the sulphides and antimonial ores abound nearer the Cordilleras. The richest mines are not far distant from Copiapo, in the mountains north of the valley of Huasco. The mines of Mt. Chanarçillo, about 16 leagues south of Copiapo, abound in horn silver, and begin to yield arsenio-sulphides at a depth of about 500 feet. The mines of Punta Brava, which are nearer the Cordilleras, afford the arsenical and antimonial ores.

In Peru, the principal mines are in the districts of Pasco, Chota, and Huantaya. Those of Pasco are 15,700 feet above the sea, while those of Huantaya are in a low desert plain, near the port of Yquique, in the southern part of Peru. The ores afforded are the same as in Chili. The mines of Huantaya are noted for the large masses of native silver they have afforded. Silver is obtained in Peru, also, in the districts of Caxamarca, Pataz, Huamanchuco, and Hualgayoc.

The Potosi mines in Bolivia, occur in a mountain of argillaceous shale, whose summit is covered by a bed of argillaceous porphyry. The ore is the ruby silver, and argentite with native silver. The district of Caracoles, between Chili and Bolivia, yields much silver.

In Europe the principal mines are those of Spain, the province of Guadalajara, where the ore is chiefly freieslebenite; of Kongsberg in Norway; of Saxony, chiefly at Freiberg; the Hartz; in Austria, Hungary, Transylvania, and the Banat; and Russia. The mines of Kongsberg occur in gneiss and hornblende slate, in a gangue of calc spar. They were especially rich in native silver.

The mines of Saxony occur mostly in gneiss, in the vicinity of Freiberg, Ehrenfriedensdorf, Johanngeorgenstadt, Annaberg, and Schneeberg.

The ores of the Hartz are mostly argentiferous copper pyrites and galena, yet the ruby silver, argentite, stephanite, occur, especially at Andreaskreutz, and the mines of that vicinity. The rock intersected by the deposits is mostly an argillaceous shale. Calcite is the usual gangue, though it is sometimes quartz.

In the Tyrol, Austria, argentite, argentiferous tetrahedrite, and mispickel occur in a gangue of quartz, in argillaceous schist. The Hungarian mines at Schemnitz and Kremnitz, occur in syenyte and hornblende porphyry, in a gangue of quartz, often with calcite or barite (heavy spar), and sometimes fluorite. The ores are argentite. tetrahedrite, galena, blende, pyritous copper and iron; and the galena and copper ores are argentiferous. France produces some silver from argentiferous galena at Huelgoet in Brittany, and the mines of Pontgibaud, Puy-de-Dome.

The Russian mines are in Kolyvan in the Altai, and Nertchinsk in the Daouria Mountains, Siberia (east of Lake Baikal). The Daouria mines afford an argentiferous galena which is worked for its silver; it occurs in a crystalline limestone. The silver ores of the Altai occur in Silurian schists in the vicinity of porphyry, which contain also gold, copper, and lead ores.

The mines of Mexico are most abundant between 18° and 24° north latitude, on the back or sides of the Cordilleras, and especially the west side; and the principal are those of the districts of Guanaxuato, Zacatecas, Fresnillo, Sombrerete, Catorce, Oaxaca, Pachuca, Real del Monte, Batopilas, and Tasco. The veins traverse very different rocks in these regions. The vein of Guanaxuato, the most productive in Mexico, intersects argillaceous and chloritic shale, and porphyry; it affords one-forth of all the Mexican silver. The Valencian mine is the richest in Guanaxuato. The Pachuca, Real del Monte, and Moro districts, are near one another. Four great parallel veins tranverse these districts, through porphyry.

In the United States the chief silver mines are in California, Nevada, Colorado, Utah, Montana, and Idaho. The principal California mines are in its southeastern counties bordering on Nevada, namely: Alpine, Mono, and Inyo; the total yield in 1874, about $1,700,000. Those of Nevada are the Washoe region, about Virginia City and the Comstock Lode; in Lander County, along Reese River Valley, etc., the chief town of which is Austin; Esmeralda County, southeast of Washoe; in Eureka County, next east of Lander; in Lincoln County, the southeastern of the State; Humboldt County to the north; White Pine, Nye and Elko counties, east and southeast of Lander County. The rocks connected with the veins in Eastern California and Western Nevada are eruptive rocks, related for the most part to andesyte (in part, named propylite) and trachyte, with some doleryte. The mines of Utah, are those of the Big and Little Cottonwood districts (which include the Emma Mine); the American Fork district, the Parley's Park district in the Wahsatch Range north of Big Cottonwood, and the East Tintic district, in which are the Eureka Hill mines; those of Arizona, the Heintzelman, etc.; of Colorado, in the San Juan region; of Northern Michigan, at the copper mines; of Canada, at Prince's Mine, Spar Island, Lake Superior.

For the years previous to 1859 the whole yield of silver from United States mines is estimated at $1,000,000. The following are the amounts for the succeeding years, as published in Jones's Senate Report (1877), those for the years 1871 to 1876, inclusive, being from estimates by J. J. Valentine.

1859	$100,000	1868	$12,000,000
1860	150,000	1869	13,000,000
1861	2,100,000	1870	17,320,000
1862	4,500,000	1871	19,286,000
1863	8,500,000	1872	19,924,429
1864	11,000,000	1873	27,483,302
1865	11,250,000	1874	29,699,122
1866	10,000,000	1875	31,635,239
1867	13,550,000	1876	39,292,924

The Comstock Lode contributed to the silver of the world first in 1861. In 1875 it yielded $14,492,350, and the rest of Nevada $6,717,636= $21,209,983; and in 1876 these amounts were 20,570,078 and 7,462,752 =$28,032,830. The $7,462,752 from the "rest of Nevada" in 1876, were divided, as follows, between its principal mining regions: Lander County, Austin district, $1,187,500; Esmeralda County, Columbus district, $1,624,789; Elko County, Cornucopia district, $460,048; Eureka County, $1,480,558; Lincoln County, Pioche or Ely district, $790,095; Nye County, Tyboe and Reveille districts, $1,450,000.

The yield in 1876 of Utah was $3,351,520; of Colorado, 3,000,000; of California, 1,800,000; of Arizona, 500,000; of Montana, 800,000; of Idaho, 300,000; of New Mexico, 400,000.

In the "Elements of Metallurgy," of J. Arthur Phillips, the yield for 1872 is given approximately, as follows:

		Lbs. Troy.
Great Britain		52,400
Norway and Sweden		15,000
Hungary, Transylvania, and the Banat		92,000
Saxony	80,000	178,000
Haruz	27,500	
Rest of Germany	60,500	
Russia		50,000
France		16,500
Italy		32,000
Spain		100,000
Peru		200,000
Bolivia		450,000
Chili		300,000
Central America		53,000
Mexico		1,000,000
United States		1,250,000
Total		3,788,900

Mr. Phillips states that the total for the year probably amounted to 4,100,000 lbs. troy, the value of which is £13,000,000, or $63,000,000. In the above the amount from the United States is diminished to make it correspond with the preceding statement for 1872.

The following table gives, in dollars, the estimated value of the world's production of silver in recent years:

	Russia.	United States.	Mexico and South America	Other Countries.
1855	600,000	....	30,000,000	10,000,000=40,600,000
1860	650,000	150,000	30,000,000	10,000,000=40,800,000
1865	700,000	11,250,000	30,000,000	10,000,000=51,950,000
1870	575,000	17,320,000	25,000,000	10,000,000=57,895,000
1875	500,000	31,635,000	25,000,000	10,000,000=67,135,000

The total for 1876 is estimated at 76 millions.

The world's production of silver for the period of twenty-six years, from 1852 to 1877, is estimated at $1,341,800,000; for the preceding twenty-two years—from 1830 to 1851, inclusive—at $600,400,000; for the preceding thirty years—from 1800 to 1830—at $799,100,000.

Native Platinum.

Isometric: but crystals seldom observed. Usually in flattened or angular grains or irregular masses. Cleavage none. Color and streak pale or dark steel-gray. Lustre metallic, shining. Ductile and malleable. H.=4–4·5. G.=16–19; 17·108, small grains; 17·608, a mass. Often slightly magnetic, and some masses will take up iron filings.

Composition. Platinum is usually combined with more or less of the rare metals iridium, rhodium, palladium, and osmium, besides copper and iron, which give it a darker color than belongs to the pure metal, and increase its hardness. A Russian specimen afforded, Platinum 78·9, iridium 5·0, osmium and iridium 1·9, rhodium 0·9, palladium 0·3, copper 0·7, iron 11·0=98·75.

Platinum is soluble in heated aqua regia. It is one of the most infusible substances known, being wholly unaltered before the blowpipe. It is very slightly magnetic, and this quality is increased by the iron it may contain.

Diff. Platinum is at once distinguished by its malleability and extreme infusibility.

Obs. Platinum was first detected in 1735 in grains in the alluvial deposits of Choco and Barbaçoa in New Granada (now U. States of Colombia), within two miles of the northwest coast of South America, where it received the name *platina,* derived from the word *plata,* meaning *silver.* Although before known, an account by Ulloa, a Spanish traveler in America in 1735, directed attention in Europe, in 1748, to the metal. It is now obtained in Novita, and at Santa Rita, and Santa Lucia, Brazil. It has been afforded most abundantly by the Urals. It occurs also on Borneo; in the sands of the Rhine; in those of the river Jocky, St. Domingo; in traces in the United States, in North Carolina; at La François Beauce, Canada; and with gold near Point Orford, on the coast of Northern California (probably derived, according to W. P. Blake, from serpentine rocks); in British Columbia.

The Ural localities of Nischne Tagilsk and Goroblagodat have afforded much the larger part of the platinum of commerce. It occurs, as elsewhere, in alluvial beds; but the courses of platiniferous alluvium have been traced to a great extent up Mount La Martiane, which consists of crystalline rocks, and is the origin of the detritus. *One* to *three* pounds are procured from 3,700 pounds of sand.

Though commonly in small grains, masses of considerable size have occasionally been found. A mass weighing 1,088 grains was brought by Humboldt from South America and deposited in the Berlin Museum. Its specific gravity was

18·94. In the year 1822, a mass from Condoto was deposited in the Madrid Museum, measuring 2 inches and 4 lines in diameter, and weighing 11,641 grains. A more remarkable specimen was found in the year 1827 in the Urals, not far from the Demidoff mines, which weighed 11½ (more accurately, 11·57) pounds troy; and similar masses are now not uncommon. The largest yet discovered weighed 21 pounds troy; it is in the Demidoff cabinet.

Russia affords annually about 35 cwt. of platinum, which is about five times the amount from Brazil, Borneo, Colombia, and St. Domingo. Borneo affords about 500 pounds per year.

The North Carolina platinum was found with gold in Rutherford County. It was a single reniform granule, weighing 2·54 grains. Other instances are reported from the Southern gold region.

The infusibility of platinum and its resistance to the action of the air, and moisture, and most chemical agents, renders it of great value for the construction of chemical and philosophical apparatus. The large stills employed in the concentration of sulphuric acid are now made of platinum; but such stills are gilt within, since platinum when unprotected is acted upon by the acid, and soon becomes porous. It is also used for crucibles and capsules in chemical analysis; for galvanic batteries; as foil, or worked into cups or forceps, for supporting objects before the blowpipe. It alloys readily when heated with iron, lead, and several of the metals, and is also attacked by caustic potash and phosphoric acid, in contact with carbon; and consequently there should be caution when heating it not to expose it to these agents.

It is employed for coating copper and brass; also for painting porcelain and giving it a steel lustre, formerly highly prized. It admits of being drawn into wire of extreme tenuity.

Platinum was formally coined in Russia. The coins had the value of 11 and 22 rubles each.

This metal fuses readily before the "compound blowpipe;" and Dr. Hare succeeded in 1837 in melting twenty-eight ounces into one mass. The metal was almost as malleable and as good for working as that obtained by the other process; it had a specific gravity of 19·8. He afterwards succeeded in obtaining from the ore masses which were 90 per cent. platinum, and as malleable as the metal in ordinary use, though somewhat more liable to tarnish, owing to some of its impurities. Deville and Debray have perfected this process, and have melted over 25 pounds of platinum in less than three-quarters of an hour. In the process the osmium present is oxidized and thus removed.

Platin-iridium. Grains of iridium have been obtained at Nischne Tagilsk, consisting of 76·8 iridium, and 19·64 platinum, with some palladium and copper. A similar platin-iridium has been obtained at Ava, in the East Indies. Another, from Brazil, contained 27·8 iridium, 55·5 platinum, and 6·9 of rhodium.

Iridosmine. A compound of iridium and osmium from the platinum mines of Russia, South America, the East Indies, and California. The crystals are pale steel-gray hexagonal prisms; usually in flat grains. H.=6·7. G.=19·5-21·1. Malleable with difficulty.

The *composition* varies. One variety, called *Newjanskite,* contains iridium 46·8, osmium 49·3, rhodium 3·2, iron 0·7. Another, *Sisserskite,* iridium 25·1, osmium 74·9, and iridium 20, osmium 80. But analysis affords also from 0·5 to 12·3 of rhodium, and 0·2 to 6·4 of the rarer metal *ruthenium,* with traces usually of platinum, copper and iron. The grains are distinguished by their superior hardness from those of platinum, and also by the peculiar odor of osmium when heated with nitre. Iridosmine is common with the gold of Northern California, and injures its quality for jewelry. Occurs sparingly in the gold washings on the rivers Du Loup and Des Plantes, Canada.

The metal iridium is extremely hard, and is used, as well as rhodium, for points to the nibs of gold pens. Its specific gravity is 21·8.

Laurite. In minute octahedrons. A ruthenium sulphide, with 3 per cent. of osmium. From platinum sands of Borneo and Oregon.

Palladium.

Isometric. In minute octahedrons. Occurs mostly in grains, sometimes composed of divergent fibres. Color steel-gray, inclining to silver-white. Ductile and malleable. H. 4·5–5. G.=11·3-12·2.

Consists of palladium, with some platinum and iridium. Fuses with sulphur, but not alone.

Obs. Occurs in Brazil with gold, and is distinguished from platinum, with which it is associated, by the divergent structure of its grains. It was discovered by Wollaston, in 1803. *Selenpalladite,* or *Allopalladium,* is native palladium in hexagonal tables from Tilkerode in the Hartz. It is reported also from St. Domingo and the Urals. *Porpezite* is palladium gold, or gold containing about 10 per cent. of palladium; three samples assayed at the Rio de Janeiro mint yielding 11·1, 9·75, and 7·7 per cent. of palladium.

This metal is malleable, and when polished has a whitish steel-like lustre which does not tarnish. A cup weighing 3¼ pounds was made by M. Breant in the mint at Paris, and is now in the *garde-meuble* of the French crown. In hardness it is equal to fine steel. 1 part fused with 6 of gold forms a white alloy; and this compound was employed, at the suggestion of Dr. Wollaston, for the graduated part of the mural circle constructed by Troughton for the Royal Observatory at Greenwich. Palladium has been employed also for certain surgical instruments.

MERCURY.

Mercury occurs native; alloyed with silver forming native amalgam; and in combination with sulphur, selenium, chlorine, or iodine, and with sulphur and antimony in some tetrahedrite. Its ores are completely volatile, excepting when silver or copper is present.

Native Mercury.

Isometric. Occurs in fluid globules scattered through the gangue. Color tin-white. G.=13·56. Becomes solid and crystallizes at a temperature of −39° F.

Mercury, or quicksilver, as it is often called (a translation of the old name "argentum vivum)," is entirely volatile before the blowpipe, and dissolves readily in nitric acid.

Obs. Native mercury is a rare mineral, yet is met with at the different mines of this metal, at Almaden in Spain, Idria in Carniola (Austria), in Hungary, Peru, and in California. It is usually in disseminated globules, but is sometimes accumulated in cavities so as to be dipped up in pails.

Mercury is used for the extraction of gold and silver ores. It is also employed for silvering mirrors, for thermometers and barometers, and for various purposes connected with medicine and the arts.

Native Amalgam. See page 117.

Cinnabar.—Mercury Sulphide.

Rhombohedral. $R \wedge R = 72° 36'$. Cleavage lateral, highly perfect. Crystals often tabular, or six-sided prisms. Also massive; sometimes in earthy coatings.

Lustre unmetallic, of crystals adamantine; often dull. Color bright red to brownish red, and brownish black. Streak scarlet-red. Subtransparent to nearly opaque. H.$=$2–2·5. G.$=$8·5–9. Sectile.

Composition. $Hg\,S_2$=Sulphur 13·8, mercury 86·2. It often contains impurities. The *liver ore*, or *hepatic cinnabar*, contains some carbon and clay, and has a brownish streak and color. The pure variety volatilizes entirely before the blowpipe.

Diff. Distinguished from red oxide of iron and chromate of lead by vaporizing before the blowpipe; from realgar by giving off on charcoal no alliaceous fumes.

Obs. Cinnabar is the ore from which the principal part of the mercury of commerce is obtained. It is when pure identical with the pigment *vermilion.* It occurs mostly in connection with siliceous, talcose and argillaceous slates, or other stratified deposits, both the most ancient and those of more recent date. The mineral is too volatile to be expected in any abundance in proper igneous or crystalline rocks, yet has been found sparingly in granite.

The localities are mentioned beyond.

Metacinnabarite is the same compound with cinnabar, but differs in crystallization; it is from Redington Mine, Lake County, California.

Guadalcazarite, of Mexico, is $Hg\,S$ in which a little of the sulphur is replaced by selenium.

Calomel or *Horn Quicksilver.* A tough, sectile mercury chloride, of a light yellowish or grayish color, and adamantine lustre, translucent or subtranslucent, crystallizing in secondaries to a square prism. H.$=$1–2. G.$=$6·48. It contains 15·1 per cent. of chlorine, and 84·9 of mercury.

Iodic Mercury. A reddish-brown ore, from Mexico.

Tiemannite. A dark steel-gray mercury selenide, from the Hartz, and the vicinity of Clear Lake, California.

Coloradoite. A grayish black mercury telluride, with G.$=$8·627. from the Keystone and Mountain Lion Mines, Colorado. (Genth.)

Magnolite. A mercurous tellurate, $Hg\,O_4\,Te$, from Magnolia district, Colorado.

General Remarks.—The following are the regions of the principal mines of mercury. At Idria, in Austria (discovered in 1497), where the ore is a dark bituminous cinnabar distributed through a blackish shale or slate, containing some native mercury; at Almaden, in Spain, near the frontier of Estremadura, in the province of La Mancha, in argillaceous beds and grit rock, which are intersected by dikes of "black porphyry" and granite—mines mentioned by Pliny as affording vermilion to the Greeks, 700 years before the Christian era; in the Palatinate on the Rhine; in Hungary; Sweden; several points in France; Ripa, in Tuscany; in Shensi, in China; at Arqueros, in

Chili ; at Huanca Velica and some other points in Peru ; at St. Onofre and other places in Mexico ; in California and Idaho.

The most noted of the California mines, New Almaden, is situated in Mine Hill, Santa Clara County, south of San Francisco. The rocks are altered Cretaceous slates, talcose in part, with beds of serpentine either side, and associated also with beds of jasper or siliceous slate. The New Idria mine is in Fresno County, in the Mt. Diablo Range, and was discovered in 1855. The rocks are more or less altered silico-argillaceous and siliceous slates and sandstones, and the cinnabar is distributed irregularly through them ; between this and the Aurora Mine on San Carlos (the highest peak of the Diablo Range, 4,977 feet), there is much serpentine (in which is chromic iron) and siliceous rock or slate. In Napa Valley, Napa County, north of San Francisco, there are other valuable mines situated in rocks closely similar, as Whitney states, to those affording quicksilver at New Almaden. They are in a serpentine belt, the cinnabar being in some places in the serpentine, but mostly in the peculiar siliceous rock associated with it. Native mercury occurs with the cinnabar.

The product of the California mines of mercury in 1874, is given as follows by Raymond, in his "Mineral Resources for 1875" :

New Almaden	Santa Clara	County	9,084	flasks.
New Idria	Fresno	"	7,000	"
Cerro Bonito	"	"	900	"
California	Napa	"	3,000	"
Manhattan	"	"	620	"
Phœnix	"	"	685	"
Washington	"	"	200	"
Redington	Lake	"	7,200	"
California Borax	"	"	570	"
Great Western	"	"	1,900	"
Buckeye	Colusa	"	700	"
Missouri	Sonoma	"	200	"
Oakland	"	"	307	"
Saint John	Solano	"	1,900	"

Which, with the additions from a few other less productive openings, make a total of 34,254 flasks, or over 2,400,000 lbs. The yield in 1867 was 44,386 flasks, or about 3,400,000 lbs. The total yield of the world in 1872, is stated by Phillips at 6,670,000 lbs. avoirdupois.

COPPER.

Copper occurs native in considerable quantities ; and also combined with oxygen, sulphur, selenium, arsenic, antimony, chlorine, and as carbonate, phosphate, arsenate, sulphate, and vanadate. The ores of copper vary in specific gravity from 3·5 to 8·5, and seldom exceed 4 in hardness.

Native Copper.

Isometric. In octahedrons; no cleavage apparent. Often in plates or masses, or arborescent and filiform shapes.

Color copper-red. Ductile and malleable. H.=2·5–3. G.=8·84.

Native copper often contains a little silver disseminated throughout it. Before the blowpipe it fuses readily, and on cooling it is covered with a black oxyd. Dissolves in nitric acid, and produces a deep azure-blue solution on the addition of ammonia.

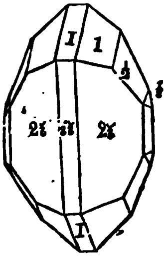
Obs. Native copper accompanies the ores of copper, and usually occurs in the vicinity of dikes of igneous rocks.

Siberia, Cornwall, and Brazil are noted for the native copper they have produced. A mass, supposed to be from Bahia, now at Lisbon, weighs 2,616 pounds. South of Lake Superior about Portage Lake on Keweenaw Point, and also, less abundantly, on the Ontanagon River, and at some other points in that region, native copper occurs mostly in veins in trap, and also in the enclosing sandstone. A mass weighing 3,704 lbs. has been taken from thence to Washington City; it is the same that was figured by Schoolcraft, in the *American Journal of Science,* volume iii., p. 201. One large mass was quarried out in the "Cliff Mine," whose weight has been estimated at 200 tons. It was 40 feet long, 6 feet deep, and averaged 6 inches in thickness. This copper contains, intimately mixed with it, about $\frac{3}{10}$ per cent. of silver. Besides this, perfectly pure silver, in strings, masses, and grains, is often disseminated through the copper, and some masses, when polished, appear sprinkled with large white spots of silver, resembling, as Dr. Jackson observes, a porphyry with its feldspar crystals. Crystals of native copper are also found penetrating masses of prehnite and analcite in the trap rock. This mixture of copper and silver cannot be imitated by art, as the two metals form an alloy when melted together. It is probable that the separation in the rocks is due to the cooling from fusion being so extremely gradual as to allow the two metals to solidify separately, at their respective temperatures of solidification—the trap being an igneous rock, and ages often elapsing, as is well known, during the cooling of a bed of lava, covered from the air. Native copper occurs sparingly in St. Ignace and Michipicoton Islands, Lake Superior.

Small specimens of native copper have been found in the States of New Jersey, Connecticut, and Massachusetts, where the Triassic formation occurs. One mass from near Somerville, N. J., weighs 78 pounds, and is said originally to have weighed 128 pounds. Within a few miles to the north of New Haven, Conn., one mass of 90 pounds, and another of 200, besides other smaller, have been found in the drift, all of which came from veins in the trap or associated Triassic sandstone. Near New Brunswick, N. J., a vein or sheet of copper, from a sixteenth to an eighth of an inch thick, has been observed and traced along for several rods.

Native copper occurs also in South Australia; it is stated that a single train from the Moonta Mine carried away at one time forty tons of native copper.

Chalcocite.—Copper Glance. Vitreous Copper Ore. Redruthite.



Trimetric. $I : I = 119° 35'$. Cleavage parallel to I, but indistinct. Also in compound crystals like aragonite. Often massive.

Color and streak blackish lead-gray; often tarnished blue or green. Streak sometimes shining. H.=2·5–3. G.=5·5–5·8.

Composition. Cu_2S=Sulphur 20·2, copper 79·8=100. B.B. on charcoal gives off fumes of sulphur, fuses easily in the exterior flame; and after the sulphur is driven off, a globule of copper remains. Dissolves in heated nitric acid, with a precipitation of the sulphur.

Diff. Resembles argentite, but it is not sectile, like that ore, and they afford different results before the blowpipe. The solution of the ore in nitric acid covers an iron plate (or knife blade) with copper, while a similar solution of the silver ore covers a copper plate with silver.

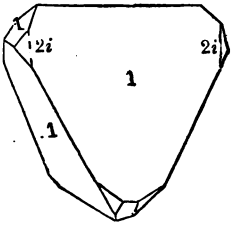
Obs. Occurs with other copper ores in beds and veins. At Cornwall, splendid crystallizations occur. Siberia, Hesse, Saxony, the Banat, Chili, etc., afford this ore.

In the United States, a vein affording fine crystallizations occurs at Bristol, Conn. Other localities are at Wolcottville, Simsbury, and Cheshire, Conn.; at Schuyler's Mines, and elsewhere, N. J.; in the U. S. copper-mine district, Blue Ridge, Orange County, Virginia; between New Market and Taneytown, Maryland; and sparingly at the copper mines of Michigan and the Western States; also at some mines north of Lake Huron; in the San Juan mining region, Colorado; north of Gila Riva, near the borders of New Mexico and Arizona; at the Bruce Mines, Lake Huron, and at Prince's Mine, Spar Island, and on Michipicoton Islands, Lake Superior.

Covellite, or *Blue Copper*. A dull blue-black massive mineral, with the composition Cu S. G=3·8. It contains 66·5 per cent. of copper.

Harrisite. A copper glance with cubic cleavage, from Canton Mine, Ga.; probably a pseudomorph after galenite.

Chalcopyrite.—Copper Pyrites. Copper-and-Iron Sulphide.



Dimetric. Crystals tetrahedral or octahedral; sometimes compound. $I \wedge I = 109° 53'$, and $108° 40'$. Cleavage indistinct. Also massive, and of various imitative shapes.

Color brass-yellow, often tarnished deep yellow, and also iridescent. Streak unmetallic, greenish black, and but little shining. H.=3·5-4. G. =4·15-4·3.

Composition. $CuFe\ S_2$ = Sulphur 34·9, copper 34·6, iron 30·5=100. Fuses B.B. to a globule which is magnetic, owing to the iron present. Gives sulphur fumes on charcoal. With soda on charcoal affords a globule of metallic iron with copper. The usual effect with nitric acid.

Diff. This ore resembles native gold, and also pyrite. It is distinguished from gold by crumbling when it is attempted to cut it, instead of separating in slices; and from pyrite in its deeper yellow color, and in yielding easily to the point of a knife, instead of striking fire with a steel.

Obs. Copper pyrites occurs in veins intersecting gneiss and other metamorphic rocks; also in those connected with eruptive rocks; and sometimes in cavities or veins in ordinary stratified rocks. It is usually associated with pyrite, and often with galenite, blende, and copper carbonates. The copper of Fahlun, Sweden, is obtained mostly from this ore, where it occurs with serpentine in gneiss. Other mines of this ore are in the Hartz, near Goslar; in the Banat, Hungary, Thuringia, etc. The Cornwall ore is mostly of this kind. As prepared for sale at Redruth it rarely yields 12 [illegible] per cent., and generally only 7 or 8, and occasionally as little as 3 to 4 per cent. of metal; "6½ per cent. of metal may be considered an average of the produce of the total quantity of ore sold." (Phillips, 1874.) Such poverty of ore is only made up by its facility of transport, the moderate expense of fuel, or the convenience of smelting. Its richness may generally be judged of from the color: if of a fine yellow hue, and yielding readily to the hammer, it is a good ore; but if hard and pale yellow it contains much pyrite, and is of poor quality.

In the United States there are many localities of this ore. It occurs in mines in Vermont, at Strafford; and at Shrewsbury, Corinth, Waterbury; also in New Hampshire, Maine, Massachusetts, and Connecticut; in New York, at the Ancram lead mine; also near Rossie, and at Wurtzboro'; in Pennsylvania, at Morgantown; in Virginia, at the Phenix copper mines, Fauquier County, and at the Walton gold mine, Luzerne County; in Maryland, in the vicinity of Liberty and New London in Frederick County; and at the Patapsco mines near Sykesville; in North Carolina, in Davidson and Guilford counties. In Michigan, where native copper is so abundant, this is a rare ore; but it occurs at Presqu'isle, at Mineral Point, and in Wisconsin, where it is the predominating ore; in Tennessee, in Polk County, at the Hiwassee mines; in the San Juan mining region, Colorado; in Lander Co., and elsewhere, Nevada; at Copperopolis, Calaveras Co., California; also at the Bruce and other mines on Lake Huron; and Michipicoton Islands, in Lake Superior.

Cubanite is a copper-and-iron sulphide, containing Sulphur 39·0, iron 38·0, copper 19·8, silica 2·3=99·12.

Bornite.—Erubescite. Variegated Copper Pyrites.

Isometric. Cleavage octahedral in traces. Occurs in octahedrons and dodecahedrons. Also massive.

Color between copper-red and pinchbeck-brown. Tarnishes rapidly on exposure. Streak pale grayish-black and but slightly shining. Brittle. H.=3. G.=5.

Composition. $Cu_3Fe\ S_3$=Sulphur 28·6, copper 55·58, iron 16·36; but varies much.

The ore of Bristol, Conn., afforded Sulphur 25·83, copper 61·79, iron 11·77=99·39.

B.B. on charcoal fuses to a brittle globule attractable by the magnet; dissolves in nitric acid, with separation of sulphur.

Diff. This ore is distinguished from the preceding by its pale reddish-yellow color, and its rapidly tarnishing and becoming of bluish and reddish shades of color, the quality to which the name *erubescite,* from the Latin word for *to blush,* alludes.

Obs. Occurs, with other copper ores, in granitic and allied rocks, and also in stratified formations. The mines of Cornwall have afforded crystallized specimens, and it is there called, from its color, "horse-flesh ore." Other foreign localities of massive varieties are Ross Island, Killarney, Ireland; Norway, Hessia, Silesia, Siberia, and the Banat.

Fine crystallizations were formerly obtained at the Bristol copper mine, Conn., in granite; and also in red sandstone, at Cheshire, in the same State, with malachite and barite. Massive varieties occur at the New Jersey mines, and in Pennsylvania.

Crookesite. A copper selenide, containing 17·25 per cent. of thallium, and a little silver.

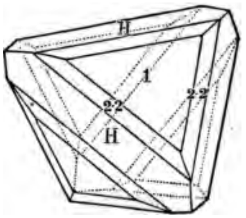
Domeykite, Algodonite and *Whitneyite* are copper arsenides; *Berzelianite,* a copper selenide; *Eucairite,* a copper-and-silver selenide.

Tennantite. A compound of copper, iron, sulphur, and arsenic. It occurs in dodecahedral crystals, brilliant, with a dark lead-gray color, and reddish-gray streak. From the Cornish mines near Redruth and St. Day in Cornwall.

Tetrahedrite.—Gray Copper. Fahlerz.

Isometric and tetrahedral. Occurs in tetrahedral forms. Cleavage octahedral in traces.

Color between steel-gray and iron-black. Streak nearly like the color, sometimes inclined to brown and cherry-red. Rather brittle. H. = 3–4·5. G. = 4·5-5·12.



Composition. $Cu_8\,S_7\,Sb_2$ $(= 4\,Cu_2\,S + Sb_2\,S_3)$, but with part of the copper replaced usually by iron and zinc, and sometimes silver or quicksilver, and part of the antimony by arsenic, and rarely bismuth. It sometimes contains 30 per cent. of silver in place of part of the copper, and is then called *argentiferous tetrahedrite.* The amount of arsenic varies from 0 to 10 per cent. One variety from Spain included 10 per cent. of platinum, and another from Hohenstein some gold. Specimens from Schwatz, and some other localities, contain 15 to 18 per cent. of mercury, and are called *Spaniolite*. A kind containing 9 to 13 per cent. of lead and 10 to 13 of silver, has been called *Malinowskite*.

Obs. The Cornish mines, Andreasberg in the Hartz, Kremnitz in Hungary, Freiberg in Saxony, Kapnik in Transylvania, and Dillenberg in Nassau, afford fine crystallizations of this ore. It is a common ore in the Chilian mines, and it is worked there and elsewhere for copper and often also for silver. Occurs also in Mexico; in Mariposa and Shasta counties, Cal.; abundantly at the Sheba and De Soto mines, Humboldt Co.; Nevada, near Austin in Lander Co.; in the San Juan region, Colorado; at the Heintzelman Mine, and the Santa Rita Mine, in Arizona; also in fine crystallizations in the caves of Huallanca, on the Peruvian Andes, at a height of about 14,700 feet, an ore yielding much silver.

Bournonite. Contains Sulphur 29·6, antimony 25·0, lead 42·24, copper 13·0=100. Its crystals are modified rectangular prisms, of a steel-gray color and streak, and are often compounded into shapes like a cog-wheel, whence it is called *wheel-ore*. H.=2·5–3. G.=5·766. From the Tyrol, Hartz, Transylvania, Saxony, Cornwall, and Siberia.

Other sulphantimonites or sulpharsenites of copper are *Chalcostibite*, *Emplectite*, *Binnite*, *Stylotypite*, *Aikinite*, *Enargite*, *Polybasite*. Polybasite contains also silver.

Atacamite.—Copper Oxichloride.

Trimetric; in rhombic prisms and other forms; also granular massive. Color green to blackish green. Lustre adamantine to vitreous. Streak apple-green. Translucent to subtranslucent. H. = 3–3·5. G. = 3·75–3·9. *Composition*, $Cu\,Cl_2 + 3\,Cu\,O_2\,H_2$=Chlorine 16·64, oxygen 11·25, copper 11·25, water 12·66=100. From the Atacama desert, between Chili and Peru, and elewhere in Chili; also from Bolivia, Vesuvius, Saxony, Spain, Cornwall.

Cuprite.—Red Copper Ore.

Isometric. In regular octahedrons, and modified forms of the same. Cleavage octahedral. Also massive, and sometimes earthy.

Color deep red, of various shades. Streak brownish red. Lustre adamantine or submetallic; also earthy. Subtransparent to nearly opaque. Brittle. H. = 3·5–4. G. =5·85–6·15.

Composition. Cu_2O = Oxygen 11·2, copper 88·8. B.B. on charcoal, yields a globule of copper. Dissolves in nitric acid. The earthy varieties have been called *tile ore*, from the color.

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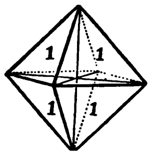

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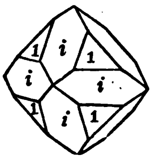

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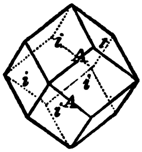


Diff. From cinnabar it differs in not being volatile before the blowpipe; and from red iron ore in yielding a bead of copper on charcoal, and copper reactions.

Obs. Occurs with other copper ores in the Banat, Thuringia, Cornwall, at Chessy near Lyons, in Siberia, and Brazil. The octahedrons are often green, from a coating of malachite.

In the United States, it has been observed crystallized and massive at Schuyler's, Somerville, and the Flemington copper mines, N. J.; also near New Brunswick, N. J.; at Bristol, Conn.; near Ladenton, Rockland County, N. Y.; in the Lake Superior region.

Tenorite, Melaconite, or *Black Copper.* An oxide of copper, CuO, occurring as a black powder, and in dull black masses and botryoidal concretions, in veins or along with other copper ores; also in iron-gray flexible scales, in the Vesuvian lavas. It is an abundant ore in some of the copper mines of the Mississippi Valley, and yields 60 to 70 per cent. of copper. It results from the decomposition of the sulphides and other ores. At the Hiwassee Mine, Polk Co., Tennessee, it has been abundant. It was formerly found of excellent quality in the Lake Superior copper region.

Chalcanthite.—Blue Vitriol. Sulphate of Copper.

Triclinic. In oblique rhomboidal prisms. Also as an efflorescence or incrustation, and stalactitic.

Color deep sky-blue. Streak uncolored. Subtransparent to translucent. Lustre vitreous. Soluble, taste nauseous and metallic. H.=2-2·5. G.=2·21.

Composition. CuO_4S+5aq=Sulphuric acid (or sulphur trioxide) 32·1, copper oxide 31·8, water 36·1. A polished plate of iron in solutions becomes covered with copper.

Obs. Occurs with the sulphides of copper as a result of their decomposition, and is often in solution in the waters flowing from copper mines. Occurs in the Hartz, at Fahlun, in Sweden, and in many other foreign copper regions; in the Hiwassee copper mine, Tennessee; the Canton mine, Georgia; at Copiapo, Chili.

Blue vitriol is much used in dyeing operations and in the printing of cotton and linen; also for various other purposes in the arts. It has been employed to prevent dry rot, by steeping wood in its solution: and it is a powerful preservative of animal substances; when imbued with it and dried, they remain unaltered. It is afforded by the decomposition of copper pyrites, in the same manner as green vitriol from iron pyrites; but it is manufactured for the arts, chiefly from old sheathing-copper, copper turnings, and copper refinery scales.

In Frederick County, Maryland, blue vitriol is made from a black earth which is an impure oxide of copper with copper pyrites.

In some mines, the solution of sulphate of copper is so abundant as to afford considerable copper, which is obtained by immersing clean iron in it, and is called *copper of cementation.* At the copper springs of Wicklow, Ireland, about 500 tons of iron were laid at one time in the pits; in about 12 months the bars were dissolved, and every ton of iron yielded a ton and a half, and sometimes nearly two tons, of a precipitated reddish mud, each ton of which produced 16 cwt. of pure copper. The Rio Tinto Mine in Spain is another instance of working the sulphate in solution. These waters yield annually 1,800 cwt. of copper, and consume 2,400 cwt. of iron.

Brochantite. An insoluble copper sulphate, containing 17·7 per cent. of sulphur trioxide. Color emerald-green. In tabular rhombic crystals, from the Urals, Retzbanya, Cornwall, Mexico, Chili, Australia. *Krisuvigite* and *Konigite* are the same species.

Langite, Cyanotrichite (Velvet copper ore), *Krönkite, Philippite, Enysite, Linarite, Dolerophanite, Hydrocyanite,* are other sulphates containing copper, the last two anhydrous; and *Connellite* is another containing chlorine, from Cornwall.

The *Copper tungstate, Cuprotungstite,* occurs of a yellowish-green color in Chili.

Olivenite.—Hydrous Copper Arsenate.

Trimetric. $I \wedge I = 92° 30'$. In prismatic crystals, and also fibrous and granular massive. Olive-green, and of other greenish shades, to liver and wood-brown. Streak olive-green to brown. Substransparent to opaque. Brittle. H.=3. G.=4·1–4·4.

Composition. $Cu_4 O_9 As_2$=Arsenic pentoxide 40·66, copper oxide 56·15, water 3·19=100. Fuses very easily, coloring the flame bluish green. B.B. fuses with deflagration, giving off arsenical fumes, and affords a brittle globule, which with soda yields metallic copper.

Obs. From Cornwall, the Tyrol, Siberia, Chili, and other places.

Besides the above, there are the following salts of copper :

Copper Arsenates.—Euchroite has a bright emerald-green color, and contains 33 per cent. of arsenic acid, and 48 of oxide of copper ; occurs in modified rhombic prisms ; H.=3·75 ; G=3·4 ; from Libethen, in Hungary. *Clinoclasite* (*Aphanesite*) is of a dark verdigris-green inclining to blue, and also dark blue; H.=2·5–3; G.=4·19–4·36. It contains 62·7 per cent. of copper oxide ; from Cornwall. *Erinite* has an emerald-green color, and occurs in mammillated coatings ; H.=4·5–5 ; G.=4·04 ; contains 59·4 per cent. of copper oxide ; from Limerick, Ireland. *Liroconite* varies from sky-blue to verdigris-green ; occurs in rhombic prisms, sometimes an inch broad ; H.=2–2·5 ; G.=2·8–2·98. *Chalcophyllite* (*copper mica*) is remarkable for its thin foliated or mica-like structure; color emerald or grass-green ; H.=2 ; G.=2·55. Contains 58 per cent. of copper oxide ; from Cornwall and Hungary. *Tyrolite* (*Copper froth*) is another arsenate of a pale apple-green and verdigris-green color ; it has a perfect cleavage ; it contains 43·9 per cent. of copper oxide ; from Hungary, Siberia, the Tyrol, and Derbyshire. *Cornwallite* and *Chlorotile*, are names of other copper arsenates. These different arsenates of copper give an alliaceous odor when heated on charcoal before the blowpipe.

Copper Phosphates.—Pseudomalachite (*Phosphochalcite, Ehlite, Dihydrite*) occurs in very oblique crystals, or massive and incrusting, and has an emerald or blackish-green color; H.=4·5–5 ; G.=4·34 ; contains 64 to 70 per cent. of copper oxide ; from near Bonn, on the Rhine, and also from Hungary. *Libethenite* has a dark or olive-green color, and occurs in crystals, usually octahedral in aspect, and massive ; H.=4 ; G.=3·6–3·8 ; contains 66·5 per cent. of oxide of copper ; from Hungary and Cornwall. Other copper phosphates are *Veszelyite, Tagilite, Isoclasite. Torbernite* is a copper-and-uranium phosphate. These phosphates give no fumes before the blowpipe, and have the reaction of phosphoric acid.

Copper Vanadates.—Volborthite is a copper-and-calcium vanadate from the Urals ; and *Mottrammite* and *Psittacinite*, copper-and-lead vanadates, the former from England, and the latter from gold mines in Silver Star district, Montana.

Rivotite. Yellowish-green copper antimonate and carbonate.

Malachite.—Green Copper Carbonate.

Monoclinic. Usual in incrustations, with a smooth tuberose, botryoidal, or stalactitic surface; structure finely and firmly fibrous. Also earthy.

Color light green, streak paler. Usually nearly opaque; crystals translucent. Lustre of crystals adamantine inclining to vitreous; but fibrous incrustations silky on a cross fracture. Earthy varieties dull. H.=3·5–4. G.=3·7–4.

Composition. $Cu_2O_4C+H_2O$=Carbon dioxide (or carbonic acid) 19·9, copper oxide 71·9, water 8·2=100. Dissolves with effervescence in nitric acid.

B.B. decrepitates and blackens, colors the flame green, and becomes partly a black scoria. With borax it fuses to a deep-green globule, and ultimately affords a bead of copper.

Diff. Readily distinguished by its copper-green color and its associations with copper ores. It resembles a siliceous ore of copper, chrysocolla, a common ore in the mines of the Mississippi Valley; but it is distinguished by its complete solution and effervescence in nitric acid. The color also is not the bluish green of chrysocolla.

Obs. Green malachite usually accompanies other ores of copper, and forms incrustations, which, when thick, have the colors banded and delicate in their shades and blending. Perfect crystals are quite rare. The mines of Siberia, at Nischne Tagilsk, have afforded great quantities of this ore. A mass, partly disclosed, measured at top 9 feet by 18; and the portion uncovered contained at least half a million pounds of pure malachite. Other noted foreign localities are Chessy, in France; Sandlodge, in Shetland; Schwatz in the Tyrol; Cornwall; the Island of Cuba; Serro do Bembe, west coast of Africa; copper mines of Australia; Chili.

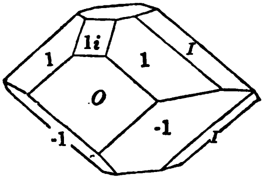
The copper mine of Cheshire, Conn., has afforded handsome specimens; also Morgantown, Perkiomen, and Phœnixville, Penn.; Schuyler's Mine, and the New Brunswick copper mine, N. J.; it occurs also in Maryland, between Newmarket and Taneytown; and in the Catoctin Mountains; in the Blue Ridge, Penn., near Nicholson's Gap; also in ntic district, Utah.

TiAt Mineral Point, Wisconsin, a bluish silico-carbonate of ocpper occurs, which is for the most part chrysocolla, or a mixture of this mineral with the carbonate.

This mineral receives a high polish and is used for tables, mantelpieces, vases; and also ear-rings, snuff-boxes, and various ornamental articles. It is not much prized in jewelry. At Versailles there is a room furnished with tables, vases, and other articles of this kind; and similar rooms are to be found in many European palaces.

Malachite is sometimes passed off in jewelry as turquois, though easily distinguished by its shade of color and much inferior hardness. It is a valuable ore when abundant; but it is seldom smelted alone, because the metal is liable to escape with the liberated volatile ingredient.

Azurite.—Blue Copper Carbonate. Blue Malachite.



Monoclinic. In modified oblique rhombic prisms, the crystals rather short and stout; lateral cleavage perfect. Also massive. Often earthy.

Color deep blue, azure blue, Berlin blue. Transparent to nearly opaque. Streak bluish. Lustre vitreous, almost adamantine. Brittle. H.=3·5–4·5. G.=3·5–3·85.

Composition. $Cu_3O_7C_2+H_2O=$ Carbon dioxide 25·6, copper oxide 69·2, water 5·2. B.B. and in acids like the preceding.

Obs. Azurite accompanies other ores of copper. Chessy, France, has afforded fine crystals; found also in Siberia; in the Banat; near Redruth in Cornwall; at Phœnixville, Pa., in crystals; in Wisconsin near Mineral Point; as incrustations, and rarely as crystals, near Sing Sing, N. Y.; near New Brunswick, N. J.; near Nicholson's Gap, in the Blue Ridge, Pa.

When abundant it is a valuable ore of copper. It makes a poor pigment as it is liable to turn green.

Aurichalcite **(*Buratite*) is a hydrous copper-and-zinc carbonate, or a cuprous hydrozincite, pale green to sky-blue in color; from the Altai, Retzbanya, Chessy in France, Tyrol, Spain, Leadhills in Scotland, and Lancaster, Pa.**

Dioptase.—Copper Silicate.

Rhombohedral. $R \wedge R=126° \ 24'$. Occurs in six-sided prisms with rhombohedral terminations. Color emerald-green. Lustre vitreous. Transparent to nearly opaque. H.=5. G.=3·28–3·35.

Composition. CuH_2O_4Si=Silica 38·1, copper oxide 50·4, water 11·5=100. B.B. with soda on charcoal yields copper, and this, with its hardness, distinguishes it from the species it resembles.

Obs. From the Khirgeez Steppes of Siberia.

Chrysocolla.—Hydrous Copper Silicate.

Usually as incrustations; botryoidal and massive. Also in thin seams and stains; no fibrous or granular structure apparent, nor any appearance of crystallization.

Color bright green, bluish green. Lustre of surface of incrustations smoothly shining; also earthy. Translucent to opaque. H.=2–4. G.=2–2·4.

Composition. $CuO_3Si+2aq$=Silica 34·2, copper oxide 45·3, water 20·5=100.

	SIBERIAN.	NEW JERSEY.		
	Von Kobell.	Berthier.	Bowen.	Beck.
Oxide of copper	40·0	55·1	45.2	42·6
Silica	36·5	35·4	37·3	40·0
Water	20·2	28·5	17·0	16·0
Carbonic acid	2·1	—	—	—
Oxide of iron	1·0	—	—	1·4

The mineral varies much in the proportion of its constituents, as it is not crystallized.

B.B. it blackens in the inner flame, and yields water without melting. With soda on charcoal yields a globule of copper.

Diff. Distinguished from green malachite as stated under that species.

Obs. Accompanies other copper ores in Cornwall, Hungary, the Tyrol, Siberia, Thuringia, etc. In Chili it is abundant at the various mines. In Wisconsin and Missouri it is so abundant as to be worked for copper. It was formerly taken for green malachite. It also occurs at the Somerville and Schuyler's mines, N. J., at Morgantown, Penn., and Wolcottville, Conn.

This ore in the pure state affords 30 per cent. of copper; but as it occurs in the rock will hardly yield one-third this amount. Still, when abundant, as it appears to be in the Mississippi Valley, it is a valuable ore.

General Remarks.—The most valuable sources of copper for the arts are *native copper*, *chalcopyrite* or "yellow copper ore," *chalcocite* or "copper glance," *bornite* or "variegated copper ore," *malachite* or "green carbonate of copper," *chrysocolla* or "silicate," *cuprite* or "red oxide of copper;" and occasionally *tenorite* or "black copper."

The principal copper regions, exclusive of the American, are as follows. The Cornwall and Devon, England, where the ore is mostly chalcopyrite; about Mansfeld, in Prussia, having the ore distributed through a bed of red shale in the Permian (Kupferschiefer), about eighteen inches thick, making about 2½ per cent. of the bed; the Urals on their western slope, in the Permian, as in Mansfeld; also more productively on the eastern side of the Urals, at the Nischne Tagilsk and Bogoslowskoi mines, in Silurian limestone where traversed by eruptive rocks, and at the Gumeschewskoi mine, in argillaceous shale, the ore chiefly malachite and cuprite; in France, at Chessy, near Lyons, of malachite and azurite, now of little value; in Norway, at Alten, and in Sweden, at Fahlun; in Hungary, at Schemnitz, Kremnitz, Kapnik, and the Banat; in Italy, at Monte Catini; in Spain, in the province of Huelva, where is the Rio Tinto mine, which affords chalcopyrite, and also the sulphate (p. 138); in Portugal, at San Domingo, near the mouth of the Guadiana; in Algeria, Turkey, China, Japan, Cape of Good Hope; in South Australia, where are three prominent mines, the Burra, Wallaroo, and Moonta, their yield in 1875, £451,500; New South Wales, the yield in 1875, about 6,000 tons, the value £508,800.

In South America, in Chili, in the vicinity of Copiapo, and less abundantly at other places to the south; in Bolivia, also in Peru, and the Argentine Republic, but not much developed. In Cuba, but much less productive than formerly.

In Eastern North America, some copper has been afforded by the Triassic of New Jersey and the Connecticut Valley, but there are no producing mines. Corinth, Vermont, and the Hiwassee mine, Tennessee, are worked. The chief sources of copper are the veins of Northern Michigan, near Lake Superior. The veins are connected with trap-dikes intersecting a red Lower Silurian sandstone as stated on page 131. The first discoveries of copper ore were made at Copper Harbor. Near Fort Wilkins the black oxide was afterward found in a large deposit, and 40,000 pounds of this ore were shipped to Boston. On further exploration in the trap, the Cliff mine, 25 miles to the westward, was laid open, where the largest masses of native copper have been found, and which still proves to be highly productive. Other veins have since been opened in various parts of the region, at Eagle Harbor, Eagle River, Grand Marais, Lac La Belle, Agate Harbor, Torch Lake, on the Ontonagon, in the Porcupine Mountains, and elsewhere. The country north of Lakes Superior and Huron, Isle Royale and the Michipicoton Islands, in Lake Superior, also afford copper ores, and the vicinity of Quebec at the Acton and Harvey Hill mines, in rocks referred to the Quebec formation.

In Western North America, in Arizona, there are large veins of copper north of the Gila, on the borders of New Mexico, where are the Santa Rita and Hanover mines, and the ores are cuprite, chalcocite, malachite; there are rich veins also in Colorado, especially in Gilpin and Park counties, in Nevada, and California.

The amount of copper produced in 1872, is stated as follows by J. Arthur Phillips (Elements of Metallurgy):

England	5,600 tons.
Prussia	8,000 "
Russia	6,500 "
Hungary	3,500 "
Sweden and Norway	2,500 "
Spain	7,500 "
Portugal	5,500 "
Japan	1,000 "
South Australia	12,000 "
South Africa	7,500 "
Chili and Bolivia	46,500 "
United States	12,600 "

The total annual production is estimated by Phillips at 126,000 to 130,000 tons.

The metal copper was known in the earliest periods and was used mostly alloyed with tin, forming *bronze*. The mines of Nubia and Ethiopia are believed to have produced a great part of the copper of the early Egyptians. Eubæa and Cyprus are also mentioned as affording this metal to the Greeks. It was employed for cutting instruments and weapons, as well as for utensils; and bronze chisels are at this day found at the Egyptian stone-quarries, that were once employed in quarrying. This bronze (*chalkos* of the Greeks, and *æs* of the Romans) consisted of about 5 parts of copper to 1 of tin, a proportion which produces an alloy of maximum hardness. Nearly the same material was used in early times over Europe; and weapons and tools have been found consisting of copper, edged with iron, indicating the scarcity of the latter metal. Similar weapons have also been found in Britain; yet it is certain that iron and steel were well known to the Romans and later Greeks, and to some extent used for warlike weapons and cutlery. Bronze is hardened by hammering or pressure.

Copper knives, axes, chisels, spear heads, bracelets, etc., have been found in the Indian Mounds of Wisconsin, Illinois, and the neighboring States; and there is evidence that the Indians, besides using drift masses of copper, knew of the copper veins of Northern Michigan, and worked them, especially in the Ontonagon region, where their tools and excavations have been discovered.

Copper at the present day is very various in its applications in the arts. It is largely employed for utensils, for the sheathing of ships, and for coinage. Alloyed with zinc it constitutes brass, and with tin it forms bell-metal as well as bronze.

Brass consists of copper 65 per cent., zinc 35; with 53·5 per cent. of zinc the alloy is silver-white; *casting brass* of 65–72 copper, 35–28 zinc; *or molu* or Dutch metal, of 70–85 copper, 15–25 zinc, with 0 3 of each, lead and tin; *brass for lathe-work* of 60–70 copper, 28–38 zinc, 2 lead; *Muntz metal*, for the sheathing of ships, 60 copper, 39 zinc, 1 lead; *spelter solder* for brass, copper 50, zinc 50.

Bronze for medals consists of copper 93, tin 7; for speculum metal, copper 60, tin 30, arsenic 10; for casting bronze, copper 82–83, tin 1–3, zinc 17–18; for gun-metal, copper 85–92, tin 8–15; for bell-metal, copper 65–80, tin 20–35, antimony 0–2; antique bronze, copper 67–95, tin 8–15, lead 0–1, zinc 0–15.

Lord Rosse used for the speculum of his great telescope, 126 parts of copper to 57½ parts of tin. The brothers Keller, celebrated for their *statue castings*, used a metal consisting of 91·4 per cent. of copper, 5·53 of zinc, 1·7 of tin, and 1·37 of lead. An equestrian statue of Louis XIV., 21 feet high, and weighing 53,263 French pounds, was cast by them in 1699, at a single jet.

An alloy of copper 90, and aluminum 10, is sometimes used in place of bronze.

LEAD.

Lead occurs rarely native; generally in combination with sulphur; also rarely with arsenic, tellurium, selenium, and in the condition of sulphate, carbonate, phosphate and arsenate, chromate and molybdate.

The ores of lead vary in specific gravity from 5·5–8·2. They are soft, the hardness of the species with metallic lustre not exceeding 3, and others not over 4. They are easily fusible before the blowpipe (excepting plumbo-resinite); and with soda on charcoal (and often alone), malleable lead may be obtained. The lead often passes off in yellow fumes, when the mineral is heated on charcoal in the outer flame, or it covers the charcoal with a yellow coating.

Native Lead.

A rare mineral, occurring in thin laminæ or globules, G.=11·35. Said to have been seen in the lava of Madeira; at Alston in Cumberland with galena; in the County of Kerry, Ireland; in an argillaceous rock at Carthagena; at Camp Creek, Montana.

Galenite.—Galena. Lead Sulphide.

Isometric. Cleavage cubic, eminent, and very easily obtained. Also coarse or fine granular; rarely fibrous.

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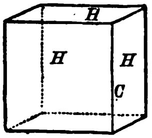

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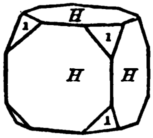

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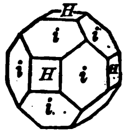


Color and streak lead-gray. Lustre shining metallic. Fragile. H.=2·5. G.=7·25–7·7.

Composition. Pb S=Sulphur 13·4, lead 86·6=100. Often contains some silver sulphide, and is then called *argentiferous galena;* and at times zinc sulphide is present. The ore of veins intersecting crystalline metamorphic rocks is most likely to be argentiferous. The proportion of silver varies greatly. In Europe, when it contains only 7 or 8 ounces to the ton it is worked for the silver. The galenite of the Hartz affords ·03 to ·05 per cent. of silver; the English ·02 to ·03 per cent.; that of Leadhills, Scotland, ·03 to ·06; that of Pike's Peak, Colorado, ·05 to ·06; that of Arkansas, ·03 to ·05; that of Middletown, Ct., ·15 to ·20; that of Roxbury, Ct., 1·85; that of Monroe, Ct., 3·0; while that of Missouri afforded Dr. Litton only ·0012 to ·0027 per cent. A little antimony or cadmium is sometimes present.

B.B. on charcoal, it decrepitates unless heated with caution, and fuses, giving off sulphur, coats the coal yellow, and finally yields a globule of lead.

Diff. Galenite resembles some silver and copper ores in color, but its cubical cleavage, or granular structure when massive, will usually distinguish it. Its reactions before the blowpipe show it to be a lead ore, and a sulphide.

Obs. Galena occurs in granite, limestone, argillaceous and sandstone rocks, and is often associated with ores of zinc, silver and copper. Quartz, barite, or calcite is generally the gangue of the ore; also at times fluor spar. The rich lead mines of Derbyshire and the northern districts of England, occur in the Subcarboniferous limestone; and the same rock contains the valuable deposits of Bleiberg, in Austria, and the neighboring deposits of Carinthia. The ore of Cornwall is in true veins intersecting slates and is argentiferous. At Freiberg in Saxony, it occupies veins in gneiss; in the Upper Hartz, and at Przibram in Bohemia, it traverses clay slate, of Lower Silurian age; at Sahla, Sweden, it occurs in crystalline limestone. There are other valuable beds of galena, in France at Poullaouen and Huelgoet, Brittany, and at Villefort, department of Lozère; in Spain in the granite and argillyte hills of Linares, in Catalonia, Grenada, and elsewhere; in Savoy; in Netherlands at Vedrin, not far from Namur; in Bohemia, southwest of Prague; in Joachimstahl, where the ore is worked principally for its silver; in Siberia in the Daouria Mountains in limestone, argentiferous and worked for the silver.

The deposits of this ore in the United States are remarkably for their extent. They occur in limestone, in the States of Missouri, Illinois, Iowa, and Wisconsin; argillaceous iron ore, pyrite, calamine and smithsonite ("dry bone" of the miners), blende ("black-jack"), carbonate of lead or cerussite, and barite or heavy spar, are the most common associated minerals; and less abundantly occur chalcopyrite and malachite, ores of copper; also occasionally the lead ores, anglesite and pyromorphite; and in the Mine La Motte region, black cobalt, and linnæite an ore of nickel.

Lead ore was first noticed in Missouri in 1700 and 1701. In 1720 the mines were rediscovered by Francis Renault and M. La Motte; and the La Motte bears still the name of the latter. Afterward the country passed into the hands of Spaniards, and during that period, in 1763, a valuable mine was opened by Francis Burton, since called *Mine à Burton*.

The lead region of Wisconsin, according to Dr. D. D. Owen, comprises 62 townships in Wisconsin, 8 in Iowa, and 10 in Illinois, being 87 miles from east to west, and 54 miles from north to south. The ore, as in Missouri, is abundant, and throughout the region there is scarcely a square mile in which traces of lead may not be found. The principal indications in the eyes of miners, as stated by Mr. Owen, are the following: fragments of calcite in the soil, unless very abundant, which then indicate that the vein is wholly calcareous or nearly so; the red color of the soil on the surface, arising from the ferruginous clay in which the lead is often imbedded; fragments of lead ("gravel mineral"), along with the crumbling magnesian limestone, and dendritic specks distributed over the rock; also, a depression of the country, or an elevation, in a straight line; or "sink-holes;" or a peculiarity of vegetation in a linear direction. The ore, according to Whitney, occupies chambers or openings in the limestone instead of true veins, and in this respect it is like that of Derbyshire and Northern England.

The mines of Wisconsin and Illinois are in Lower Silurian limestone of the Trenton period, called the Galena limestone; those of Southeastern Missouri, situated chiefly in Franklin, Jefferson, Washington, St. François, St. Genevieve, and Madison counties, are in the "Third Magnesian limestone;" also Lower Silurian, but, of the Calciferous or Potsdam period; those of Southwestern Missouri, situated mostly in Newtown, Jasper, Lawrence, Green and Dade counties, and in the western part of McDonald, Barry, Stone, and Christian counties, are in the "Keokuk limestone," of the Subcarboniferous period, but partly in Webster, Taney, Christian, and Barry counties, in the Lower Silurian "magnesian limestone;" those of Central Missouri, situated in Moniteau, Cole, Miller, Morgan, and other counties, are mostly in the Lower Silurian "magnesian limestone," but partly, as in Northern Moniteau, in the Subcarboniferous. The conditions in which the ore occurs in Missouri confirms the opinion of Prof. Whitney, as to there being no true veins. Mr. Adolf Schmidt, in his account of the Missouri lead ores, says that the deposits contain red clay, broken chert, from the chert bed, and portions of the limestone beds, along with the lead; that the barite was introduced after the lead; that some caves are filled through all their ramifications, while others are only partly filled; and he adds that the same solvent waters that made the caves and horizontal fissures or openings may have held the various minerals in solution. In Derbyshire, England, the deposits contain fossils of Permian rocks, showing that, although occurring in Subcarboniferous limestone, they were much later in origin.

Galenite also occurs in the region of Chocolate River and elsewhere, Lake Superior copper region; on Thunder Bay, and Black Bay; at Cave-in-Rock in Illinois, along with fluorite; in New York at Rossie, St. Lawrence County, in gneiss, in a vein 3 to 4 feet wide; near Wurtzboro' in Sullivan County, a large vein in millstone grit; at Ancram, Columbia County; Martinsburg, Lewis County, N. Y., and Lowville; in Maine, at Lubec; also of less interest at Blue Hill Bay, Birmingham and Parsonsfield; in New Hampshire, at Eaton, Bath, Tamworth and Haverhill; in Vermont, at Thetford; in Massachusetts, at Southampton, Leverett, and Sterling, but without promise to the miner; at Newburyport, Mass., in a vein which is now worked; at Middletown, Ct., formerly worked as a silver-lead mine; in Virginia, in Wythe County, Louisa County, and elsewhere; in North Carolina, at King's Mine, Davidson County, where the lead appears to be abundant; in Tennessee, at Brown's Creek, and at Haysboro', near Nashville; in Pennsylvania, at Phœnixville; in Michipicoton and Spar Islands, Lake Superior. In Nevada it is abundant on Watkins River, and at Steamboat Springs, Galena district; in Colorado, at Pike's Peak, etc.; in Arizona, in the Patagonian Mts., Santa Rita

Mts., and in Yuma County; in the Castle Dome, Eureka, and other districts, where the ore is worked for the silver it contains.

The lead of commerce is obtained from this ore. It is also employed in glazing common stoneware: for this purpose it is ground up to an impalpable powder and mixed in water with clay; into this liquid the earthen vessel is dipped and then baked.

Lead Selenides and Tellurides.

These various ores of lead are distinguished by the fumes before the blowpipe, and by yielding, on charcoal, ultimately, a globule of lead.

Clausthalite, or *lead selenide,* has a lead-gray color, and granular fracture, and is occasionally foliated. H.=2·5–3. G.=7·6–8·8. B.B. on charcoal a horse-radish odor (that of selenium). From the Hartz. There is a *lead and copper selenide* (*Zorgite*) which has the sp. gr. 7–7·5. A *lead-and-mercury selenide* (*Lehrbachite*) occurs in foliated grains or masses of a lead-gray to bluish and iron-black color.

Altaite, or *lead telluride.* A tin-white cleavable mineral, with H.=3–3·5, and G.=8·16. From the Altai Mountains.

Nagyagite, or *Foliated tellurium,* is a less rare species, remarkable for being foliated like graphite; color and streak blackish lead-gray; H.=1–1·5, G.=7·085. It contains Tellurium 32·2, lead 54·0, gold 9·0, with often silver, copper, and some sulphur. From Transylvania.

Antimonial and Arsenical Sulphides of lead. These include *Sartorite, Zinkenite, Plagionite, Jamesonite, Dufrenoysite, Boulangerite, Kobellite, Meneghinite, Geocronite;* also *Brongniardite* and *Freieslebenite,* in which silver is also present, and *Stylotypite* and *Aikenite* in which copper is also present.

Minium.—Oxide of Lead.

Pulverulent. Color bright red, mixed with yellow. G.=4·6. *Composition,* $Pb_3\ O_4$. Affords globules of lead in the reduction flame of the blowpipe.

Obs. Occurs at various mines, usually associated with galena, and is found abundantly at Austin's Mines, Wythe County, Virginia, with white lead ore.

Uses. Minium is the *red lead* of commerce; but for the arts it is artificially prepared.

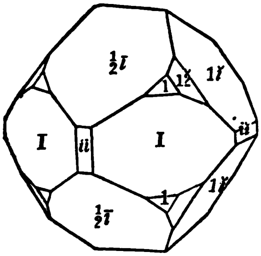
Plumbic ochre is lead protoxide, of a yellow color.

Mendipite. Color white, yellowish or reddish, nearly opaque. Lustre pearly. G.=7–7·1. $PbCl_2 + PbO$=Chloride of lead 38·4, lead oxide 61·6. From Mendip Hills, Somersetshire. *Cotunnite* is a chloride of lead, $PbCl_2$, occurring at Vesuvius in white acicular crystals. It contains 74·5 per cent. of lead.

Plumbogummite. In globular forms, having a lustre somewhat like gum arabic, and a yellowish or reddish-brown color. H.=4–4·5.

G.=6·3–6·4. Also a variety 4–4·9. Consists of **lead, alumina, and water.** From Huelgoet in Brittany, and at a lead mine in Beaujeu; also from the Missouri mines, with black cobalt, and from Canton mine, Ga.

Anglesite.—Lead Sulphate.



PHŒNIXVILLE.

Trimetric. In rhombic prisms and other forms. Lateral cleavage. $I \wedge I = 103° 43\frac{1}{2}'$. Also massive; lamellar or granular.

Color white or slightly gray or green. Lustre adamantine; sometimes a litte resinous or vitreous. Transparent to nearly opaque. Brittle. H.=2·75–3. G.=6·1–6·4.

Composition. Pb O_4 S, affording about 73 per cent. of oxide of lead. B.B. fuses in the flame of a candle, and, on charcoal, yields lead with soda.

Diff. Resembles aragonite and some other earthy species; but this and the other ores of lead are at once distinguished by specific gravity, and also by their yielding lead in blowpipe trials. Differs from the carbonate of lead in lustre and in not dissolving with effervescence in acid.

Obs. Usually associated with galena, and results from its decomposition. Occurs in fine crystals at Leadhills and Wanlockhead, Great Britain, and also at other foreign lead mines. In the United States, it is found at the lead mines of Missouri and Wisconsin; in splendid crystallizations at Phœnixville, Pa.; sparingly at the Walton gold mine, Louisa County, Va.; at Southampton, Mass.; in Arizona, and in Cerro Gordo, Cal.

Caledonite is a lead-and-copper sulphate, of azure-blue color. It is remarkable for a very perfect cleavage in one direction. G.=6·4. From Leadhills and Roughten Gill, England; also from Mine la Motte, Missouri.

Lead selenate. A sulphur-yellow mineral, occurring in small globules, and affording before the blowpipe on charcoal a garlic odor, and finally a globule of lead. It is named *Kerstenite.*

Crocoite.—Crocoisite. Lead Chromate.

Monoclinic. In oblique rhombic prisms, massive, of a bright red color and translucent. Streak orange-yellow. H.=2·5–3. G.=5·9–6·1.

Composition. $Pb\,O_4\,Cr$ = Chromium trioxide 31·1, lead oxide 68·9. Blackens and fuses, and forms a shining slag containing globules of lead.

Obs. Occurs in gneiss at Beresof in Siberia, and also in Brazil. This is the *chrome yellow* of the painters.

Phœnicochroite (*or Melanochroite*) is another lead chromate, containing 23·0 of chromium trioxide, and having a dark red color; streak brick-red. Crystals usually tabular and reticulately arranged. G.=5·75. From Siberia.

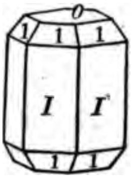
Vauquelinite. A lead and copper chromate, of a very dark green or pearly black color, occurring usually in minute irregularly aggregated crystals; also reniform and massive. H.=2·5–3. G.=5·5–5·8. From Siberia and Brazil; also at the lead mine near Sing Sing, in mammillary concretions.

Stolzite, or *lead tungstate.* In square octahedrons or prisms. Color green, gray, brown, or red. Lustre resinous. H.=2·5–3. G.=7·9–8·1. Contains 51 of tungstic acid and 49 of lead.

Wulfenite, or *lead molybdate.* In dull-yellow octahedral crystals, and also massive. Lustre resinous. Contains molybdenum trioxide 34·25, protoxide 64·42. From Bleiberg and elsewhere in Carinthia; also Hungary. It has been found in small quantities in the Southampton lead mine, Mass., and in fine crystals, at Phœnixville, Penn.

Lead Sulphato-carbonates. There are two whitish or grayish ores of this composition called *Lanarkite* and *Leadhillite.* The former contains 71 per cent. of carbonate of lead; the latter, 47.

Pyromorphite.—Lead Phosphate.



Hexagonal. In hexagonal prisms; often in crusts made of crystals. Also in globules or reniform, with a radiated structure.

Color bright green to brown; sometimes fine orange-yellow, owing to an intermixture with chromate of lead. Streak white or nearly so. Lustre more or less resinous. Nearly transparent to subtranslucent. Brittle. H.=3·5–4. G.=6·5–7·1.

Composition. $Pb_3O_8P_2 + \frac{1}{3}PbCl_2$ = Phosphorus pentoxide 15·71, lead oxide 82·27, chlorine 2·62 =100·60. B.B. fuses easily in the forceps, coloring the flame bluish green. On charcoal fuses, and on cooling, the globule becomes angular; the coal is coated white from the chloride, and nearer the assay, yellow from lead oxide. Soluble in nitric acid.

Diff. Has some resemblance to beryl and apatite; but is quite different in its action before the blowpipe, and much higher in specific gravity.

Obs. Leadhills, Wanlockhead, and other lead mines of Europe are foreign localities. In the United States, very handsome crystallized specimens occur at King's Mine, in Davidson County, N. C.; other localities are the Perkiomen and Phœnixville mines, Pa.; the Lubec lead mines, Me.; Lenox, N. Y.; formerly, a mile south of Sing Sing, N. Y.; and the Southampton lead mine, Mass.

The name *pyromorphite* is from the Greek *pur*, fire, and *morphe*, form, alluding to its crystallizing on cooling from fusion before the blowpipe.

Mimetite. A lead arsenate, resembling pyromorphite in crystallization, but giving a garlic odor on charcoal before the blowpipe. Color pale yellow, passing into brown. H.=2·75–3·5. G.=6·41. Composition, $Pb_3 O_8 As_2 + \frac{1}{3} Pb Cl_2$=Arsenic pentoxide 23·20, lead oxide 74·96, chlorine 2·30=100·55. From Cornwall and elsewhere; Phœnixville, Pa.

Hedyphane is a variety of mimetite containing much lime. It occurs amorphous, of a whitish color, and adamantine lustre. H.=3·5–4. G.=5·4–5·5.

Karyinite. A lead arsenate containing manganese and calcium, from Norway.

Ecdemite. A lead chloro-arsenate.

Vanadinite. A lead vanadate occurring in hexagonal prisms like pyromorphite, and also in implanted globules. Color yellow to reddish brown. H.=2·75–3. G.=6·6–7·3. From Mexico; also from Wanlockhead in Dumfriesshire.

Monimolite. A yellow lead antimonate.

Nadorite. A yellow lead chlor-antimonate.

Bindheimite. A hydrous lead antimonate.

Cerussite.—White Lead Ore. Lead Carbonate.

Trimetric. In modified right rhombic prisms, and often in compound crystals, two or three crossing one another as in fig. 2. $I \wedge I = 117° 13'$. Also in six-sided prisms like aragonite. Also massive; rarely fibrous.

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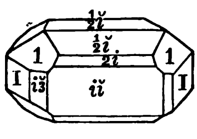

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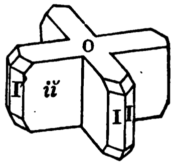

Color white, grayish, light or dark. Lustre adamantine. Brittle. H.=3–3·5. G.=6·46–6·48.

Composition. PbO_3C=Carbon dioxide 16·5, lead oxide 83·5=100. B.B. decrepitates, fuses, and with care on charcoal affords a globule of lead. Effervesces in dilute nitric acid.

Diff. Like anglesite, distinguished from most of the species it resembles by its specific gravity and yielding lead when heated. From anglesite it differs in giving lead *alone* before the blowpipe, as well as by its solution and effervescence with nitric acid, and its less glassy lustre.

Obs. Associated usually with galena. Leadhills, Wanlockhead, and Cornwall have afforded splendid crystallizations; also Linares, in Spain, and other lead mines on the continent of Europe.

In the United States, handsome specimens are obtained at Austin's Mines, Wythe County, Virginia, and at King's Mine, in Davidson's County, North Carolina; at the latter place it has been worked for lead, and it is associated with native silver and pyromorphite. Perkiomen and Phœnixville, Penn., afford good crystals. It occurs also at "Vallée's Diggings," Jefferson County, Missouri, and other mines, in that State; at Brigham's Mine, near the Blue Mounds, Wisconsin, partly in stalactites; at "Deep Diggings," in crystals; and at other places, both massive and in fine crystallizations.

When abundant, this ore is wrought for lead. Large quantities occur about the mines of the Mississippi Valley. It was formerly buried up in the rubbish as useless, but it has since been collected and smelted. It is an exceedingly rich ore, affording in the pure state 75 per cent. of lead.

Carbonate of lead is the "white lead" of commerce, so extensively used as a paint. The material for this purpose is, however, artificially made.

Phosgenite or *Corneous Lead.* A chloro-carbonate of lead, occurring in whitish adamantine crystals. H.=2·75–4. G.=6–6·31. Composition, $PbO_3C+PbCl_2$. From Derbyshire and Germany.

Hydrocerussite. Hydrous lead carbonate. From Sweden.

Ganomalite is a white lead-manganese silicate, affording 34·89 per cent. of lead oxide. From Sweden. *Hyalotecite* is a lead-barium-lime silicate. Both are from Longban, Sweden.

General Remarks.—The lead of commerce is derived almost wholly from the sulphide of lead or galenite, the localities of which have already been mentioned. In some mining regions, the carbonate and sulphate are abundant.

The lead mines of the Central United States afforded in 1826, 1,770 tons; in 1842, 17,340 tons; and of late years, 12,000 to 15,000 tons.

Nevada produced 10,000 tons in 1870, and 50,000 in 1875. According to Phillips, England produced in 1872, 60,450 tons; Prussia, in 1871, 49,500 tons; Spain, in 1873, 102,600 tons; France, 2,500 tons; Italy, 15,500 tons; Austria, 10,000 tons.

ZINC.

Zinc occurs in combination with sulphur and oxygen; and also in the condition of silicate, carbonate, sulphate, and arsenate. It is also a constituent of one variety of the species spinel. The chief sources of the metal are smithsonite or the carbonate; willemite and calamine, or silicates; zincite, or the oxide; sphalerite (blende), or the sulphide; and franklinite.

Sphalerite.—Blende. Zinc Sulphide.

Isometric. In dodecahedrons, octahedrons, and other allied forms, with a perfect dodecahedral cleavage. Also massive; sometimes fibrous. Color wax-yellow, brownish-yellow, to black, sometimes green, red and white; streak white, to reddish brown. Lustre resinous or waxy, and brilliant on a cleavage face; sometimes submetallic. Transparent to subtranslucent. Brittle. H.=3·5–4. G.=3·9–4·2. Some specimens become electric with friction, and give off a yellow light when rubbed with a feather.

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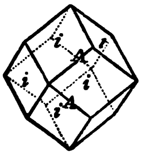

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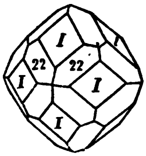

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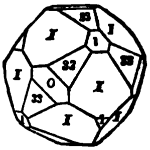


Composition. Zn S=Sulphur 33, zinc 67=100. Contains frequently a portion of iron sulphide when dark colored; often also 1 or 2 per cent. of cadmium sulphide, especially the red variety. Nearly infusible alone and with borax. Dissolves in nitric acid, emitting sulphuretted hydrogen. Strongly heated on charcoal yields fumes of zinc.

Diff. This ore is characterized by its waxy lustre, perfect cleavage, and its being nearly infusible. Some dark varieties look a little like tin ore, but their cleavage and inferior hardness distinguish them; and some clear red crystals, which resemble garnet, are distinguished by the same characters and also by their very difficult fusibility.

Obs. Occurs in rocks of all ages, and is associated generally with ores of lead; often also with copper, iron, tin, and silver ores. The lead mines of Missouri and Wisconsin afford this ore abundantly. Other localities are in Maine, at Lubec, Bingham, Dexter, Parsonsfield; in New Hampshire, at Eaton, Warren, Haverhill, Shelburne; in Vermont, at Hatfield; in Connecticut, in Brookfield, Berlin, Roxbury, and Monroe; in New York, at Ancram lead mine, the Wurtzboro' lead vein, at Lockport, Root, 2 miles southeast of Spraker's Basin, in Fowler, at Clinton; at Franklin, N. J., colorless (*Cleiophane*); in Pennsylvania, at the Perkiomen lead mine; in Virginia, at Austin's lead mine, Wythe County; in Tennessee, near Powell's River, and at Haysboro'; at Prince's Mine, Spar Island, Lake Superior, with ores of silver; in Beauce Co., Canada, where it is slightly auriferous. This ore is the *Black-jack* of miners.

Blende is a useful ore of zinc, though more difficult of reduction than calamine. By its decomposition (like that of pyrite), it affords sulphate of zinc or white vitriol.

Wurtzite is zinc sulphide in hexagonal crystals from Bolivia. *Huascolite* and *Youngite* are zinc-lead sulphides.

Zincite.—Red Zinc Ore. Red Zinc Oxide.

Hexagonal. Usually in foliated masses, or in disseminated grains; cleavage eminent, nearly like that of mica; but the laminæ brittle, and not so easily separable.

Color deep or bright red; streak orange-yellow. Lustre brilliant, subadamantine. Translucent or subtranslucent. H.=4–4·5. G.=5·4–5·7. Thin scales by transmitted light deep yellow.

Composition. ZnO=Oxygen 19·7, zinc 80·3=100. B.B. infusible alone, but yields a yellow transparent glass with borax; on charcoal, a coating of zinc oxide. Dissolves in nitric acid without effervescence.

Diff. Resembles red stilbite, but distinguished by its infusibility and also by its mineral associations.

Obs. Occurs with franklinite at Mine Hill and Sterling Hill, Sussex County, N. J.

A good ore of zinc, and easily reduced.

Voltzite. A compound of sulphur, oxygen and zinc, $4ZnS+ZnO$. Occurs in implanted globules of a dirty rose-red color, with a pearly lustre on a cleavage surface. From France, and near Joachimstahl.

Goslarite.—Sulphate of Zinc. White Vitriol.

Trimetric. Cleavage perfect in one direction. $I \wedge I = 90° 42'$.

Color white. Lustre vitreous. Easily soluble; taste astringent, metallic, and nauseous. Brittle. H.=2–2·5. G.=1·9–2·1.

Composition. ZnO_4S+7 aq.=Zinc oxide 28·2, sulphur trioxide 27·9, water 43·9=100. B.B. gives off fumes of zinc on charcoal, which cover the coal.

Obs. Results from the decomposition of blende. Occurs in the Hartz, in Hungary, in Sweden, and at Holywell in Wales.

Sulphate of zinc is extensively employed in medicine and dyeing. For these purposes it is prepared to a large extent from blende by decomposition, though this affords, owing to its impurities, an impure sulphate. It is also obtained by direct combination of zinc with sulphuric acid.

White Vitriol, as the term is used in the arts, is one form of sulphate of zinc, made by melting the crystallized sulphate, and agitating till it cools and presents an appearance like loaf sugar.

Köttigite. A hydrous zinc-cobalt arsenate of reddish color (owing to presence of cobalt) from Schneeberg

Adamite. A hydrous zinc-arsenate of honey-yellow to violet color, from Chili.

Smithsonite.—Carbonate of Zinc.

Rhombohedral. $R \wedge R = 107° 40'$. Cleavage R perfect. Massive or incrusting; reniform and stalactitic.

Color impure white, sometimes green or brown; streak uncolored. Lustre vitreous or pearly. Subtransparent to translucent. Brittle. H.=5. G.=4·3–4·45.

Composition. ZnO_3C=Carbon dioxide 35·2, zinc oxide 64·8 (*four-fifths* of which is pure zinc)=100. Often contains some cadmium. B.B. infusible alone, but carbonic acid and oxide of zinc are finally vaporized. Effervesces in nitric acid. Negatively electric by friction.

Diff. The effervescence with acids distinguishes this mineral from the following species; and the hardness, difficult fusibility, and the zinc fumes before the blowpipe, from the carbonate of lead or other carbonates. Besides, the crystals over a drusy surface terminate usually in sharp three-sided pyramids.

Obs. Occurs commonly with galena or blende, and usually in calcareous rocks. Found in Siberia, Hungary, Silesia; at Bleiberg in Carinthia; near Aix-la-Chapelle in the Lower Rhine, and largely in Derbyshire and elsewhere in England. In the United States, it is abundant at Vallée's Diggings in Missouri, and at other lead "diggings" in Iowa and Wisconsin; also in Claiborne County, Tenn. Sparingly also at Hamburg, near the Franklin Furnace, N. J.; at the Perkiomen lead mine, Pa., and at a lead mine in Lancaster County.

Hydrozincite is a hydrous zinc carbonate, $Zn\,O_3\,C+2\,Zn\,O_2\,H$, of a whitish color, with G. =3·58–3·8.

Aurichalcite is a hydrous carbonate of zinc and copper, occurring in drusy incrustations of acicular crystals, having a pale verdigris-green color. From Siberia, Hungary, England, and Lancaster, Pa.

Buratite is a lime aurichalcite.

Willemite.—Zinc Silicate. Troostite.

Rhombohedral. $R \wedge R=116^\circ\ 1'$. In hexagonal prisms, and also massive.

Color whitish, greenish yellow, apple-green, flesh-red, yellowish brown. Streak uncolored. Transparent to opaque. Brittle. H. =5·5. G. =3·89–4·18.

Composition. $Zn\,O_3\,Si$=Silica 27·1, zinc oxide 72·9=100. B.B. fuses with difficulty to a white enamel; on charcoal, and most easily on adding soda, yields a coating which is yellow while hot, and white on cooling, and which, moistened with cobalt solution and treated in O.F., is colored bright green. Gelatinizes with hydrochloric acid.

Obs. From Moresnet, between Liège and Aix-la-Chapelle; Raibel in Carinthia; Greenland. Abundant at both Franklin and Sterling, mixed with zincite, and used as an ore of zinc; also in prismatic crystals that occasionally are six inches long.

Calamine.—Hydrous Zinc Silicate. Galmei.

Trimetric. In rhombic prisms, the opposite extremities with unlike planes. $I \wedge I=104^\circ\ 13'$. Cleavage perfect parallel to *I*. Also massive and incrusting, mammillated or stalactitic.

Color whitish or white, sometimes bluish, greenish, or brownish. Streak uncolored. Transparent to translucent. Lustre vitreous or subpearly. Brittle. H. =4·5–5. G. = 3·16–3·9. Pyro-electric.

Composition. $Zn_2 O_4 Si + aq.$ = Silica 25·0, zinc oxide 67·5, water 7·5=100.

B.B. alone it is almost infusible. Forms a clear glass with borax. In heated sulphuric acid it dissolves, and the solution gelatinizes on cooling.

Diff. Differs from calcite and aragonite by its action with acids; from a salt of lead, or any zeolite, by its infusibility; from chalcedony by its inferior hardness, and its gelatinizing with heated sulphuric acid; and from smithsonite by not effervescing with acids, and by the rectangular aspect of its crystals over a drusy surface.

Obs. Occurs with calamine. In the United States it is found at Vallée's Diggings, Mo.; at the Perkiomen and Phœnixville lead mines; on the Susquehanna, opposite Selinsgrove; at Friedensville in Saucon Valley, two miles from Bethlehem, Pa., with massive blende. Abundantly at Austin's Mines, Wythe County, Va. Valuable as an ore of zinc.

Hopeite is a rare mineral occurring in grayish-white crystals or massive, with calamine, and supposed to be a hydrous zinc-phosphate.

Franklinite, an ore of iron, manganese and zinc, is described under iron, on page 179.

General Remarks.—The metal zinc (*spelter* of commerce) is supposed to have been unknown in the metallic state to the Greeks and Romans. It has been long worked in China, and was formerly imported in large quantities by the East India Company.

The principal mining regions of zinc in the world are in Upper Silesia, at Tarnowitz and elsewhere; in Poland; in Carinthia, at Raibel and Bleiberg; in Netherlands at Limberg; at Altenberg, near Aix-la-Chapelle in the Prussian province of the Lower Rhine; in England, in Derbyshire, Alstonmoor, Mendip Hills, etc.; in the Altai in Russia; besides others in China, of which little is known. In the United States, smithsonite and calamine occur with the lead of the West in large quantities. They were formerly considered worthless and thrown aside, under the name of "dry bone." In Tennessee, Claiborne County, there are workable mines of the same ores. Calamine occurs at Friedensville, Pennsylvania, along with massive blende: the bed has been, but is not now worked. The zincite, willemite, and franklinite of Franklin, New Jersey, are together worked as a zinc ore, and both zinc and zinc oxide are produced. Blende is sufficiently abundant to be worked at the Wurtzboro' lead mine, Sullivan County, New York; at Eaton and Warren, in New Hampshire: at Lubec, in Maine; at Austin's Mine, Wythe County, Virginia, and at some of the Missouri lead mines.

The amount of zinc produced in 1872, in Europe, was about 45,745 tons for Belgium; 55,744 for Germany; 3,000 for Austria; 15,000 for Great Britain; 4,400 for France; 4,400 for Spain: making the total amount 128,289 tons. In the United States the amount of zinc made in 1875 was about 15,000 tons; of zinc oxide, 8,500 tons.

Zinc is a brittle metal, but admits of being rolled into sheets when heated to about 212° F. In sheets it is extensively used for roofing and other purposes; it being of more difficult corrosion, much harder, and also very much lighter than lead. It is also employed largely for coating (that is, making what is called *galvanized*) iron. Its alloys with copper (page 144) are of great importance.

The white oxide of zinc is much used for white paint, in place of white lead; and also in making a glass for optical purposes.

An impure oxide of zinc, called *cadmia,* often collects in large quantities in the flues of iron and other furnaces, derived from ores of zinc mixed with the ores undergoing reduction. A mass weighing 600 pounds was taken from a furnace at Bennington, Vt. It has been observed in the Salisbury iron furnace, and at Ancram, in New Jersey, where it was formerly called *Ancramite.*

CADMIUM.

There is but a single known ore of this rare metal. It is a sulphide, and is called *Greenockite.* It occurs in hexagonal prisms, with dissimilar pyramidal termination, of a light yellow color, high lustre, and nearly transparent. H.=3–3·5. G.=4-8–5. From Bishopton, Scotland.

Cadmium is often associated with zinc in sphalerite and calamine. The cadmiferous sphalerite is called *Przibramite.*

The metal cadmium is white like tin, and is so soft that it leaves a trace upon paper. It fuses at 442° F. It was discovered by Stromeyer in 1818.

TIN.

Tin has been reported as occurring native in the gold washings of the Ural, and in Bolivia. There are two ores, a sulphide and an oxide. It also occurs in some ores of columbium, tantalum, and tungsten.

Stannite.—Tin Pyrites, Sulphuret of Tin. Tin Sulphide.

Commonly massive, or in grains. Color steel-gray to iron-black; streak blackish. Brittle. H.=4. G.=4·3–4·6.

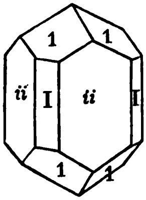
Composition. Sulphur 30, tin 27, copper 30, iron 13=100.

Obs. From Cornwall, where it is often called *bell-metal ore,* from its frequent bronze appearance; also from Ireland and the Erzgebirge.

Cassiterite.—Tin Ore. Tin Oxide.

Dimetric. In square prisms and octahedrons; often compounded. $1 \wedge 1 = 121^\circ\ 40'$; $1i \wedge 1i$ (over the summit) $112^\circ\ 10'$, (over a terminal edge) $133^\circ\ 31'$. Cleavage indistinct. Also massive, and in grains.

1.



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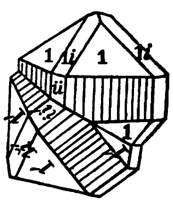


Color brown or black, with a high adamantine lustre when in crystals. Streak pale gray to brownish. Nearly transparent to opaque. H.=6–7. G.=6·4–7·1.

Composition. SnO_2=Oxygen 21·33, tin 78·67; often contains a little iron, and sometimes tantalum.

B.B. alone infusible. On charcoal with soda, affords a globule of tin.

Stream tin is the gravel-like ore found in debris in low grounds. *Wood tin* occurs in botryoidal and reniform shapes with a concentric and radiated structure; and *toad's-eye tin* is the same on a small scale.

Diff. Tin ore has some resemblance to a dark garnet, to black zinc blende, and to some varieties of tourmaline. It is distinguished by its infusibility, and its yielding tin before the blowpipe on charcoal with soda. It differs from blende also in its superior hardness.

Obs. Tin ore occurs in veins in the crystalline rocks, granite, gneiss, and mica slate, associated often with wolfram, copper and iron pyrites, topaz, tourmaline, mica or talc, and albite. Cornwall is one of its most productive localities. It is also worked in Saxony, at Altenberg, Geyer, Ehrenfriedersdorf and Zinnwald; in Austria, at Schlackenwald and other places; in Malacca, Pegu, China, and especially the Island of Banca in the East Indies; in Queensland and Northern New South Wales, Australia, in large quantities; in Greenland. It occurs also in Galicia, Spain; at Dalecarlia in Sweden; in Russia; in Mexico at Durango; and Bolivia. In the *United States* it has been found sparingly at Chesterfield and Goshen, Mass.; in some of the Virginia gold mines; in Lyme and Jackson, N. H.; and in the Temescal Range, California.

General Remarks.—The principal tin mines now worked, are those of Cornwall, Banca, Malacca, and Australia.

The Cornwall mines were worked long before the Christian era.

Herodotus, 450 years before Christ, is believed to allude to the tin islands of Britain under the cabalistic name *Cassiterides*, derived from the Greek *kassiteros*, signifying *tin*. The Phœnicians are allowed to have traded with Cornubia (as Cornwall was called, it is supposed from the horn-like shape of this extremity of England). The Greeks residing at Marseilles were the next to visit Cornwall, or the isles adjacent, to purchase tin; and after them came the Romans, whose merchants were long foiled in their attempts to discover the tin market of their predecessors.

Camden says: "It is plain that the ancient Britons dealt in tin mines from the testimony of Diodorus Siculus, who lived in the reign of Augustus, and Timaus, the historian in Pliny, who tells us that the Britons fetched tin out of the Isle of Icta (the Isle of Wight), in their little wicker boats covered with leather. The import of the passage in Diodorus is that the Britons who lived in those parts dug tin out of a rocky sort of ground, and carried it in carts at low water to certain neighboring islands; and that from thence the merchants first transported it to Gaul, and afterwards on horseback in thirty days to the springs of Eridanus, or the city of Narbona, as to a common mart. Æthicus too, another ancient writer, intimates the same thing, and adds that he had himself given directions to the workmen." In the opinion of the learned author of the Britannica here quoted, and others who have followed him, the Saxons seem not to have meddled with the mines, or, according to tradition, to have employed the Saracens; for the inhabitants of Cornwall to this day call a mine that is given over working *Attal-Sarasin*, that is, the leavings of the Saracens.

The Cornwall veins, or *lodes*, mostly run east and west, with a dip—*hade*, in the provincial dialect—varying from north to south; yet they are very irregular, sometimes crossing each other, and sometimes a promising vein abruptly narrows or disappears; or again they spread out into a kind of bed or *floor*. The veins are considered worth working when but three inches wide. The gangue is mostly quartz, with some chlorite. Much of the tin is also obtained from beds of loose stones or gravel (called *shodes*), and courses of such gravel or tin debris are called *streams*, whence the name *stream tin*.

The Australian mines are mainly in the New England district of Northern New South Wales, and the adjoining part of Queensland, and a large part of the ore goes north through Queensland. The value of the tin exported in 1875 from Queensland was £88,224, and from New South Wales (Ann. Rep. Dept. of N. S. W. Mines, 1876), £561,311, corresponding to 6,058 tons of tin in ingots, besides 2,022 tons of ore. The value of all the tin raised in N. S. Wales, prior to 1875 is £866,461. Beechwood, Victoria, also affords a little tin.

The annual production of tin in 1871 in Great Britain was 11,320 tons, and in Banca and Malacca, 7,500.

Tin is used in castings, and also for coating other metals, especially iron and copper. Copper vessels thus coated were in use among the Romans, though not common. Pliny says that the tinned articles could scarcely be distinguished from silver, and his use of the words *incoquere* and *incoctilia* seems to imply, as a writer states, that the process was the same as for the iron wares of the present day, by *immersing the vessels in melted tin.* Its alloys with copper are mentioned on page 144.

Tin is also used extensively as tinfoil; but most tinfoil consists beneath the surface of lead, and is made by rolling out plates of lead coated with tin. With quicksilver it is used to cover glass in the manufacture of mirrors. Tin oxide (dioxide), obtained by chemical processes, is employed, on account of its hardness, in making a paste for sharpening fine cutting instruments, and also to some extent in the preparation of enamels. The *chlorides* of tin are important in the precipitation of many colors as lakes, and in fixing and changing colors in dyeing and calico-printing. The bisulphide has a golden lustre, and was termed *aurum musivum*, or *mosaic gold*, by the alchemists. It is much used for ornamental painting, for paper-hangings and other purposes, under the name of bronze powder.

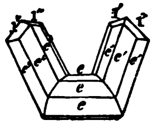
TITANIUM.

Titanium occurs in nature combined with oxygen, forming titanium dioxide or titanic acid, and also in oxygen combinations with iron and calcium, and in some silicates. It has not been met with native.

The ores are infusible alone before the blowpipe, or nearly so. Their specific gravity is between 3·0 and 4·5.

Rutile.

Dimetric. In prisms of four, eight, or more sides, with pyramidal terminations, and often bent as in the figure; $1 \wedge 1 = 123° 7\frac{1}{2}'$. Crystals often acicular, and penetrating quartz. Sometimes massive. Cleavage lateral, somewhat distinct.



Color reddish-brown to nearly red; streak very pale brown. Lustre submetallic-adamantine. Transparent to opaque. Brittle. H.=6–6·5. G.=4·15–4·25.

Composition. TiO_2 = Oxygen 39, titanium 61 = 100. Sometimes contains iron, and has nearly a black color; this variety is called *Nigrine*. B.B. alone unaltered; with salt of phosphorus a colorless bead, which in the reducing flame becomes violet on cooling.

Diff. The peculiar subdamantine lustre of rutile, and brownish-red color, much lighter red in splinters, are striking characters. It differs from tourmaline, idocrase, and augite, by being unaltered when heated alone before the blowpipe; and from tin ore, in not affording tin with soda; from sphene in its crystals.

Obs. Occurs imbedded in granite, gneiss, mica schist syenyte, and in granular limestone. Sometimes associated with hematite, as at the Grisons. Yrieix in France, Castile, Brazil, and Arendal in Norway, are some of the foreign localities.

In the United States, it occurs in crystals in Maine, at Warren; in New Hampshire, at Lyme and Hanover; in Massachusetts, at Barre, Windsor, Shelburne, Leyden, Conway; in Connecticut, at Monroe and Huntington; in New York, near Edenville, Warwick, Amity, at Kingsbridge, and in Essex County at Gouverneur; in Pennsylvania, in Chester County; in the District of Columbia, at Georgetown; in North Carolina, in Buncombe County; in Georgia, in Lincoln and Habersham counties; at Magnet Cove in Arkansas.

The specimens of limpid quartz, penetrated by long acicular crystals, are often very handsome when polished. A remarkable specimen of this kind was obtained in Northern Vermont, and less handsome ones are not uncommon; they are found in North Carolina. Polished stones of this kind are called *flèches d'amour* (love's arrows) by the French.

This ore is employed in painting on porcelain, and quite largely for giving the requisite shade of color and enamel appearance to artificial teeth.

Octahedrite (*Anatase*); *Brookite*. These species have the same composition as rutile. Octahedrite occurs in slender nearly transparent octahedrons, of a brown color. $1 \wedge 1 = 97° 51'$. H.=5·5–6. G.=3·8–3·95. From Dauphiny, the Tyrol, and Brazil; at Smithfield, R. I.

Brookite is met with in thin hair-brown flat trimetric crystals, attached by one edge. Also in thick iron-black crystals, as in the variety called *Arkansite*. H.=5·5–6. From Dauphiny; Snowdon in Wales; Ellenvilie, Ulster County, N. Y.; Paris, Maine; gold washings of North Carolina; Magnet Cove, Arkansas (Arkansite).

Perofskite. In cubic crystals, of yellow, brown, and black colors; chemical formula $(Ti, Ca)_2 O_3$. From the Urals, the Tyrol, and Magnet Cove, Arkansas.

Besides the ores here described, titanium is an essential constituent also of *ilmenite* (titanic iron), and of the silicates *titanite* or *sphene* (p. 290), *keilhauite* (p. 291), *warwickite*; and occurs also in the zirconia and yttria ores *æschynite*, *ærstedite*, and *polymignite*, and in some other rare species; sometimes in *pyrochlore*.

COBALT. NICKEL.

Cobalt has not been found native. The ores of cobalt are sulphides, arsenides, arseno-sulphides, an oxide, a carbonate, a phosphate, and an arsenate; and nickel is often associated with cobalt in the sulphides and arsenides. The ores having a metallic lustre vary in specific gravity from 6·2 to 7·2; and the color is nearly tin-white or pale steel-gray, inclined to copper-red. The ores without a metallic lustre have a clear red or reddish color, and specific gravity of nearly 3. Cobalt is often present also in arsenopyrite (or mispickel), and sometimes in pyrite.

The ores of nickel are sulphides, arsenides, arseno-sulphides, and antimono-sulphides, a sulphate, carbonate, silicates, arsenate; and the metal is a constituent of several cobalt ores, and also often of pyrrhotite (magnetic pyrites). Specific gravity between 3 and 8; hardness of one 3, but mostly between 5 and 6. Those of metallic lustre resemble some cobalt ores; but they do not give a deep blue color with borax.

Linnæite.—Cobalt Sulphide. Cobalt and Nickel Sulphide.

Isometric. In octahedrons and cubo-octahedrons; also massive. Color pale steel-gray, tarnishing copper red. Streak blackish gray. H.=5·5. G.=4·8–5.

Composition. Co_3S_4=Sulphur 42·0, cobalt 5·80=100; but with part of the cobalt replaced by nickel; copper sometimes present. *Siegenite* is a variety containing 30 to 40 per cent. of nickel. B.B. on charcoal yields sulphurous odor and a magnetic globule; often also arsenical fumes.

Obs. From Sweden, Prussia; Mine la Motte in Missouri (*Siegenite*); Mineral Hill in Maryland. Sometimes called *cobalt pyrites.*

Millerite.—Nickel Sulphide. Capillary Pyrites.

Rhombohedral. Usually in capillary or needle-like crystallizations; sometimes like wool. Also in columnar crusts and radiated. Color brass-yellow, inclining to bronze-yellow, with often a gray iridescent tarnish. Streak bright. Brittle. H.=3–3·5. G.=4·6–5·65.

Composition. NiS=Sulphur 35·6, nickel 64·4=100. In the open tube sulphurous fumes. B.B. on charcoal fuses to a globule; and after roasting, gives, with borax and salt of phosphorus, a violet bead in O.F., which in R.F. becomes gray from reduced metallic nickel.

Obs. From Joachimstahl, Przibram, Riechelsdorf; Saxony; Cornwall; at the Sterling Mine, Antwerp, N. Y.; at the Gap Mine, Lancaster Co., Pa.; at St. Louis, Mo., in capillary forms, and sometimes wool-like, in cavities in magnesian limestone. A valuable ore of nickel.

Beyrichite has the formula $Ni_5 S_7$.

Smaltite.—Cobalt Glance. Chloanthite.

Isometric. Occurs in octahedrons, cubes, and dodecahedrons, and other forms. See figs. 1, 2, 3, page 17, and 17, 27, page 20. Cleavage octahedral, somewhat distinct. Also reticulated; often massive.

Color tin-white, sometimes inclining to steel-gray. Streak grayish black. Brittle. Fracture granular and uneven. H.=5·5–6. G.=6·4–7·2.

Composition. $(Co, Ni) As_2$; the ore being either a *cobalt* arsenide, or *cobalt-nickel* arsenide; and graduating into the *nickel* arsenide called *Chloanthite.* The cobalt in the ore may constitute 23·5 per cent.; but it may be wholly absent as in the chloanthite. In addition, iron often replaces part of the other metals, as in the variety *Safflorite.*

In the closed tube gives a sublimate of metallic arsenic; in the open tube a white sublimate of arsenous oxide, and sometimes traces of sulphurous acid. B.B. on charcoal, affords an arsenical odor, fuses to a globule which gives reaction for iron, cobalt, and nickel.

Diff. Arsenopyrite (mispickel) has tho white color of smaltite, but it yields sulphur as well as arsenic, and in a closed tube affords arsenic sulphide, orpiment and realgar.

Obs. Usually in veins with ores of cobalt, silver, and copper. Occurs in Saxony, especially at Schneeberg; also in Bohemia, Hessia, and Cornwall.

In the United States it is found in gneiss with copper nickel (niccolite), at Chatham, Conn.

Cobaltite.

Isometric. Crystals like those of pyrite, but silver-white in color with a tinge of red, or inclined to steel-gray. Streak grayish black. Brittle. H.=5·5. G.=6·63.

Composition. $Co\,S_2 + Co\,As_2 = Co\,AsS$ = Arsenic 45·2, sulphur 19·3, cobalt 35·5=100, but often with much iron and occasionally a little copper. Unaltered in the closed tube; but in the open tube, yields sulphurous fumes and a white sublimate of arsenous oxide. B.B. on charcoal yields sulphur and arsenic and a magnetic globule; with borax a cobalt-blue globule.

Diff. Unlike smaltite affords sulphur, and has a reddish tinge in its white color.

Obs. From Sweden, Norway, Siberia, and Cornwall. Most abundant in the mines of Wehna in Sweden, first opened in 1809.

Niccolite.—Copper Nickel. Arsenical Nickel.

Hexagonal. Usually massive. Color pale copper-red. Streak pale brownish-red. Lustre metallic. Brittle. H.=5–5·5. G.=7·3–7·7.

Composition. $NiAs$=Nickel 44, and arsenic 56; sometimes part of the arsenic is replaced by antimony. Gives off arsenical (alliaceous) fumes before the blowpipe, and fuses to a pale globule, which darkens on exposure. Assumes a green coating in nitric acid, and is dissolved in aqua-regia.

Diff. Distinguished from pyrite and linnæite by its pale reddish shade of color, and also its arsenical fumes, and from much of the latter by not giving a blue color with borax. None of the ores of silver with a metallic lustre have a pale color, excepting native silver itself.

Obs. Accompanies cobalt, silver, and copper ores in the mines of Saxony, and other parts of Europe; also sparingly in Cornwall.

It is found at Chatham, Conn., in gneiss, associated with white nickel or cloanthite.

Skutterudite. A cobalt arsenide of the formula $CoAs_3$, from Skutterud, Norway.

Breithauptite or *Antimonial Nickel.* $NiSb$=Antimony 67·8, nickel 32·2=100. It has a pale copper-red color, inclining to violet. H.=5·5–6. G.=7·54. Crystals hexagonal. From Andreasberg.

Gersdorffite. A nickel arsenosulphide; $NiS_2 + NiAs_2 = NiAsS$= Arsenic 45·5, sulphur 19·4, nickel 35·1, but varying much in composition. Color sulphur-white to steel-gray. H.=5·5. G.=5·6–6·9.

Ullmannite or *Nickel Stibine.* An antimonial nickel sulphide, containing 25 to 28 per cent. of nickel. Color steel-gray, inclining to silver-white. In cubical crystals, and also massive. H.=5–5·5. G.=6·45. From the Duchy of Nassau.

Grünauite or *Bismuth Nickel.* A sulphide containing 31 to 38·5 of sulphur, 10 to 14 per cent. of bismuth, with 22 to 40·7 of nickel. Color light steel-gray to silver-white; often tarnished yellowish. H.=4·5. G.=5·13. From the district of Altenkirchen, Prussia.

Asbolite.—Earthy Cobalt. Black Cobalt Oxide.

Earthy, massive. Color black or blue-black. Soluble in muriatic acid, with an evolution of fumes of chlorine.

Obs. Occurs in an earthy state mixed with oxide of manganese as a bog ore, or secondary product. Abundant at Mine La Motte, Missouri, and also near Silver Bluff, South Carolina. The analyses vary in the proportion of oxide of cobalt associated with the manganese, as the compound is a mere mixture. Sulphide of cobalt occurs with the oxide. The Carolina ores afforded Cobalt oxide 24, manganese oxide 76. The ore from Missouri, as analyzed by Prof. Silliman, afforded 40 per cent. of cobalt oxide, with oxides of nickel, manganese, iron and copper.

This ore has been found abroad in France, Germany, Austria, and England.

The ore is purified and made into smalt, for the arts.

Erythrite.—Cobalt Bloom. Hydrous Cobalt Arsenate.

Monoclinic. In oblique crystals having a highly perfect cleavage, like mica; laminæ flexible in one direction. Also as an incrustation, and in reniform shapes, sometimes stellate.

Color, peach-red, crimson-red, rarely grayish or greenish; streak a little paler, the dry powder lavender-blue. Lustre of laminæ pearly; earthy varieties without lustre. Transparent to subtranslucent. H.=1·5–2. G.=2.95.

Composition. $Co_3O_8As_2+8aq$=Arsenic acid 38·4, oxide of cobalt 37·6, water 24·0. B.B. on charcoal gives arsenical fumes and fuses; yields a blue glass with borax.

The earthy ore is sometimes called *peach-blossom ore*, from its color; and also *red cobalt ochre*. *Köttigite* is a kind containing zinc.

Diff. Resembles red antimony, but that species wholly volatilizes before the blowpipe. From red copper ore it differs in giving a blue glass with borax; moreover, the color of the copper ore is more sombre.

Obs. Occurs with ores of lead and silver, and other cobalt ores. Schneeberg, in Saxony; Saalfield, in Thuringia; and Riechelsdorf, in Hessia, are noted European localities. It is found also in Dauphiny, Cornwall, and Cumberland.

Valuable as an ore of cobalt when abundant.

Roselite is a rose-red triclinic arsenate of cobalt.

Bieberite or *Cobalt Vitriol.* Has a flesh-red or rose-red tint, and astringent taste. CoO_4S+7aq = Sulphuric acid 28·4, cobalt oxide 25·5, water 46·1.

Morenosite. A nickel vitriol, NiO_4S+7aq, having apple-green to greenish-white color. *Lindackerite,* hydrous nickel-copper arsenate.

Zaratite or *Emerald Nickel.* Incrusting, minute globular or stalactitic. Color bright emerald-green. Lustre vitreous. Transparent or nearly so. H.=3-3·25. G.=2·5-2·7. It is a nickel carbonate, containing nearly 30 per cent. of water. B.B. infusible alone, but loses its color. Occurs with chromic iron and magnesium carbonate on serpentine, in Lancaster County, Pennsylvania.

Remingtonite. A hydrous cobalt carbonate, rose-colored, from Finksburg, Md.

Spherocobaltite. A cobalt carbonate, CoO_3C, from Saxony.

Nickel Silicates. *Genthite* is a hydrous magnesium and nickel silicate, of a pale apple-green color, yielding in one analysis 30 per cent. of nickel oxide. From Texas, Lancaster County, Pa., and other localities. *Röttisite,* from Röttis, Voigtland, is similar. *Pimelite* is an impure apple-green silicate, affording in one case 15·6 per cent. of nickel oxide. *Alipite* is similar; so also *Garnierite* (and *Noumeite*), from New Caledonia, and worked there for nickel.

General Remarks.—The two arsenical ores of cobalt afford the greater part of the cobalt of commerce. The earthy oxide when abundant is a profitable source of the metal. Erythrite (Cobalt Bloom) occurs abundantly with other cobalt ores at its localities in Saxony, Thuringia and Hesse Cassel. Arsenopyrite (mispickel) yields at times 5 to 9 per cent. of cobalt. Cobalt is never employed in the arts in a metallic state, as its alloys are brittle and unimportant. It is chiefly used for painting porcelain and pottery, and is required for this purpose in the state of an oxide, or the silicated oxide called smalt and azure. *Zaffre* is an impure oxide obtained in the calcining of the ore with twice its weight of sand; and from it the smalt and azure are produced. Nickel is worked in Germany, Austria, Russia, Sweden, England, United States, and New Caledonia. It is obtained largely from the copper nickel (niccolite) and chloanthite, or from an artificial product called *speiss* (an impure arsenide), derived from roasting ores of cobalt containing nickel; from siegenite (or nickel-linnæite), a sulphide of cobalt and nickel; from millerite), in part; from the apple-green silicate; and largely from pyrrhotite or "magnetic iron pyrites." At the Gap Mine, near Lancaster, Pa., the ore is millerite and pyrrhotite; in Missouri, the siegenite; in New Caledonia, chiefly the silicate.

Nickel also occurs in meteoric iron, forming an alloy with the iron, which is characteristic of most meteorites. The proportion sometimes exceeds 20 per cent.

As nickel does not rust or oxidize (except when heated), it is superior to steel for the manufacture of many philosophical instruments. An alloy of copper, nickel, and zinc (one-sixth to one-third nickel), constitutes the *German silver,* or *argentane.*

"German silver" is not a very recent discovery. In the reign of William III., an act was passed making it felony to *blanch copper* in imitation of silver, or mix it with silver for sale. "*White copper*" has long been used in Saxony for various small articles; the alloy employed is stated to consist of copper 88·00, nickel 8·75, sulphur with a little antimony 0·75, silex, clay, and iron 1·75. A similar alloy is well known in China, and is smuggled into various parts of the East Indies, where it is called *packfong*. It has been sometimes identified with the Chinese *tutenague*. M. Meurer analyzed the white copper of China, and found it to consist of copper 65·24, zinc 19·52, nickel 13, silver 2·5, with a trace of cobalt and iron. Dr. Fyfe obtained copper 40·4, nickel 31·6, zinc 25·4, and iron 2·6. It has the color of silver, and is remarkably sonorous. It is worth in China about one-fourth its weight of silver, and is not allowed to be carried out of the empire.

An alloy of 88 per cent. copper and 12 per cent. nickel is the material of the United States cent, introduced in 1851. Switzerland, Belgium and Jamaica also have used a nickel alloy for coins.

Nickel is mostly used at the present time for nickel-plating by electro-deposition. The value of the metal in commerce rose in the years 1870 to 1875, from $1.25 to $3.00 per pound. The amount annually produced is about 600 tons.

URANIUM.

Uranium ores have a specific gravity not above 7, and a hardness below 6. The ores are either of some shade of light green or yellow, or they are dark brown or black and dull, or submetallic and without a metallic lustre when powdered. They are not reduced when heated with carbonate of soda; and the brown or black species fuse with difficulty on the edges or not at all.

Uraninite.—Pitchblende. Uranium Oxide.

Isometric. In octahedrons and related forms. Also massive and botryoidal. Color grayish, brownish, or velvet-black. Lustre submetallic or dull. Streak black. Opaque. H.=5·5. G.=6·47.

Composition. 75 to 87 per cent. of uranium oxides with silica, lead, iron, and some other impurities. Related to the spinel group. B.B. infusible alone; a gray scoria with borax. Dissolves slowly in nitric acid, when powdered.

Obs. Occurs in veins with ores of lead and silver in Saxony, Bohemia, and Hungary; also in the tin mines of Cornwall, near Redruth. In the United States, very sparingly at Middletown, Redding, and Haddam, Conn.; in North Carolina; on the north side of Lake Superior (Coracite).

The oxides of uranium are used in painting upon porcelain, yielding a fine orange in the enameling fire, and a black color in that in which the porcelain is baked.

Cleveite. Hydrated oxide of uranium, iron, erbium, cerium, yttrium, in cubic forms. From Norway.

Gummite. An amorphous uranium ore, looking like gum, of a reddish or brownish color. It is a hydrous uraninite, and has resulted from its alteration. Occurs at Johanngeorgenstadt, and in North Carolina.

Eliasite. Another hydrous ore, more or less resin-like in aspect, of a reddish-brown to black color.

Hatchettolite. A hydrous columbo-tantalate of uranium, in isometric octahedrons, resembling pyrochlore from North Carolina. G.= 4·76–4·84.

Blomstrandite. A hydrous titano-columbate, from Sweden.

Torbernite.—Uranite. Chalcolite. Uran-Mica.

Dimetric. In square tables, thinly foliated parallel to the base, almost like mica; laminæ brittle.

Color emerald and grass-green; streak a little paler. Lustre of laminæ pearly. Transparent to subtranslucent. H.=2–2·5. G.=3·4–3·6.

Composition. A uranium-copper phosphate, consisting if pure of Phosphorus pentoxide 15·1, uranium trioxide 61·2, copper oxide 8·4, water 15·3=100. B.B. fuses to a blackish mass, and colors the flame green.

Diff. The micaceous structure, connected with the bright green color and square tabular form of the crystals, are striking characters. The folia of mica are not brittle, like those of uranite.

Obs. Occurs with uranium, silver and tin ores. It is found at St. Symphorien, in splendid crystallizations, near Redruth and elsewhere in Cornwall; in the Saxon and Bohemian mines; in North Carolina.

Autunite is similar to torbernite; but has a bright citron-yellow color, and is a uranium-calcium phosphate. From the same mining regions, also from near Autun in France, and sparingly, from Portland, Middletown, and Redding, Conn.; Acworth, N. H.; Chesterfield, Mass.; and in North Carolina.

Uranospinite is an autunite containing arsenic instead of phosphorus; and *Zeunerite* is a torbernite containing arsenic instead of phosphorus.

Samarskite (formerly named *uranotantalite* and *yttroilmenite*) is a compound of oxyd of uranium with columbic and tungstic acids, from Miask in the Ural. It is of a dark brown color and submetallic lustre. H=5·5. G.=5·4–5·7. Abundant in North Carolina.

Johannite or *Uranvitriol* is a sulphate of uranium. It has a fine emerald-green color, and a bitter taste. From Bohemia.

Trögerite and *Walpurgite* are uranium arsenates. *Voglite* and *Liebigite* are uranium carbonates. *Johannite* is a uranium vitriol; *Uranochalcite, Medijdite, Zippeite, Voglianite, Uraconite,* are other uranium sulphates.

Uranocircite is a hydrous barium-uranium phosphate.

IRON.

Iron occurs native, and alloyed with nickel in meteoric iron. Its most abundant ores are the oxides and sulphides. It is also found combined with arsenic, forming arsenides and sulpharsenides; with oxygen and other metals, as chromium, aluminum, magnesium; and in the condition of sulphate, phosphate, arsenate, columbate, silicate and carbonate, of which the last is an abundant and valuable ore. Its ores are widely disseminated. The oxides and silicates are the ordinary coloring ingredients of soils, clays, earth and many rocks, tinging them red, yellow, dull green, brown and black.

The ores have a specific gravity below 8, and the ordinary workable ores seldom exceed 5. Many of them are infusible before the blowpipe, and nearly all minerals containing iron become attractable by the magnet after heating, when not so before. By their difficult fusibility, the species with a metallic lustre are distinguished from ores of silver and copper, and also more decidedly from these and other ores by blowpipe reaction.

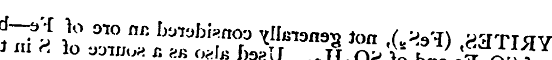
Native Iron.

Isometric. Usually massive with octahedral cleavage.

Color and streak iron-gray. Fracture hackly. Malleable and ductile. H.=4·5. G.=7·3–7·8. Acts strongly on the magnet.

Obs. Native iron occurs in grains disseminated through some doleryte, basalt, and other related igneous rocks; and in Greenland, in very large masses in such igneous rocks, the largest weighing over a ton. It is suggested by J. Lawrence Smith, that the iron was reduced by means of carbohydrogen vapors, taken into the rock from carbonaceous rocks passed through on the way to the surface.

It is a constituent of nearly all meteorites, and the chief ingredient in a large part of them; and in this state it is with a rare exception alloyed with nickel, and with traces of cobalt and copper. The Texas meteorite, of Yale College, weighs 1,635 pounds; the Pallas meteorite, now at Vienna, originally 1,600; but one in Mexico, the San Gregorio meteorite, is stated to weigh five tons; and one in the district of Chaco-Gualamba, S. A., nearly *fifteen tons.* Meteoric iron often has a very broad crystalline structure, long lines and triangular figures being developed by putting nitric acid on a polished surface. The coarseness of this structure differs in different meteorites, and serves to distinguish specimens not identical in origin. Nodules of troilite (FeS), and schreibersite (iron phosphide) are common in iron meteorites. Meteoric iron may be worked like ordinary malleable iron. The nickel diminishes the tendency to rust. But some kinds contain iron chloride, or are open in texture, and



Isometric. Usually in cubes, the striæ of one face at right angles with those of either adjoining face, as in fig. 1. Also figs. 2 to 7; also figs. 8 to 15 on page 6. Fig. 6, a pentagonal dodecahedron, is a common form. Occurs also in imitative shapes, and massive.

Color brass-yellow; streak brownish black. Lustre of crystals often splendent metallic. Brittle. H.$=6$–$6\cdot5$, being hard enough to strike fire with steel. G.$=4\cdot8$–$5\cdot1$.

Composition. FeS_2 = Sulphur $53\cdot3$, iron $46\cdot7=100$. B.B. on charcoal gives off sulphur, and ultimately affords a globule attractable by the magnet.

Pyrite often contains a minute quantity of gold, and is then called *auriferous pyrite.* See under Gold. Nickel, cobalt and copper occur in some pyrite.

Diff. Distinguished from copper pyrites in being too hard to be cut by a knife, and also in its paler color. The ores of silver, at all resembling pyrite, instead of having its pale bronze-yellow color, are steel-gray or nearly black; and besides, they are easily scratched with a knife and quite fusible. Gold is sectile and malleable.

Obs. Pyrite is one of the most common ores on the globe. It occurs in rocks of all ages. Cornwall, Elba, Piedmont, Sweden, Brazil, and Peru, have afforded magnificent crystals. Alston Moor, Derbyshire, Kongsberg in Norway, are well-known localities. It has also been observed in the Vesuvian lavas, and in many other igneous rocks.

In the United States, the localities are numerous. Fine crystals have been met with at Rossie, N. Y.; at many other places in that State; also in each of the New England States and in Canada; in New Jersey, Pennsylvania, Virginia, North Carolina, Georgia, in Colorado, Wyoming and the States west. It occurs in all gold regions, and is one source of gold.

This species is of the highest importance in the arts, although not affording good iron on account of the difficulty of separating entirely the sulphur. It affords the greater part of the sulphate of iron (green vitriol or copperas) and sulphuric acid (oil of vitriol) of commerce, and also a considerable portion of the sulphur and alum. To make the sulphate the pyrites is sometimes heated in clay retorts, by which about 17 per cent. of sulphur is distilled over and collected. The ore is then thrown out into heaps, exposed to the atmosphere, when a change ensues by which the remaining sulphur and iron become through oxidation sulphate of iron. The material is lixiviated, and partially evaporated, preparatory to its being run off into vats or troughs to crystallize. In other instances, the ore is coarsely broken up and piled in heaps and moistened. Fuel is sometimes used to commence the process, which afterwards the heat generated continues. Decomposition takes place as before, with the same result. Cabinet specimens of pyrite, especially granular or amorphous masses, often undergo a spontaneous change to the sulphate, particularly when the atmosphere is moist.

Pyrite, owing to its tendency to oxidation, and its very general distribution in rocks of all kinds and ages, is one of the chief sources of the disintegration and destruction of rocks. No granite, sandstone, slate, or limestone, containing it, is fit for architectural purposes or for any outdoor uses. The same destructive effects come from pyrrhotite and marcasite, which also are widely diffused.

The name *pyrites* is from the Greek *pur*, fire, because, as Pliny states, "there was much fire in it," alluding to its striking fire with steel. This ore is the *mundic* of miners.

Marcasite or *White iron pyrites.* This ore has the same composition as pyrites, but differs in crystallizing in trimetic forms. $I \wedge I = 106° 36'$. The color is a little paler than that of pyrite, and it is more liable to decomposition; hardness the same; specific gravity 4·6–4·85. *Radiated pyrites, Hepatic pyrites, Cockscomb pyrites* (alluding to its crested shapes), and *Spear pyrites*, are names of some of its varieties. It occurs in crystals at Warwick and Phillipstown, N. Y. Massive varieties are met with at Cummington, Mass.; Monroe, Trumbull, and East Haddam, Conn.; and at Haverhill, N. H.

Pyrrhotite.—Magnetic Pyrites. Iron Sulphide.

Hexagonal. Occurs occasionally in hexagonal prisms, which are often tabular; generally massive.

Color between bronze-yellow and copper-red; streak dark grayish-black. Brittle. H.=3·5 - 4·5. G.=4·4 - 4·65. Slightly attracted by the magnet. Liable to speedy tarnish.

Composition. $Fe_7 S_8$=Sulphur 39·5, iron 60·5. It is often a valuable ore of nickel, containing sometimes 3 to 5 per cent. of this metal. B.B. on charcoal in the outer flame it is converted into red oxide of iron. In the inner flame it fuses and glows, and affords a black globule which is magnetic, and has a yellowish color on a surface of fracture.

Diff. Its inferior hardness and shade of color, and its magnetic quality distinguish it from pyrite; and its paleness of color from chalcopyrite or copper pyrites.

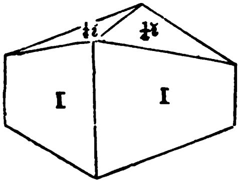
Obs. Crystallized specimens have been found at Kongsberg in Norway, and at Andreasberg in the Hartz. The massive variety is found in Cornwall, Saxony, Siberia, and the Hartz; also at Vesuvius and in meteoric stones.

In the United States, it is met with at Trumbull and Monroe, New Fairfield, and Litchfield, Conn.; at Strafford and Shrewsbury, Vt.; at Corinth, New Hampshire; in many parts of Massachusetts and New York; at Lancaster, Pa., where it is worked for nickel. It is used for making green vitriol and sulphuric acid, like pyrite.

Troilite is a similar mineral of the formula FeS, occurring in meteorites. *Schreibersite* is a phosphide of iron and nickel, occurring in meteorites.

Arsenopyrite.—Mispickel. Arsenical Iron Pyrites.

Trimetric. In rhombic prisms, with cleavage parallel to the faces I; $I \wedge I = 111° 40'$ to $112°$. Crystals sometimes elongated horizontally, producing a rhombic prism of 100° nearly, with I and I the end planes. Occurs also massive.



Color silver-white; streak dark grayish-black. Lustre shining. Brittle. H. = 5·5–6. G. = 6·3.

Composition. $FeAsS$ = Arsenic 46·0, sulphur 19·6, iron 34·4 = 100. A cobaltic variety contains 4 to 9 per cent. of cobalt in place of part of the iron; *Danaite* of New Hampshire, consists of Arsenic 41·4, sulphur 17·8, iron 32·9, cobalt 6·5. B.B. affords arsenical fumes, and a globule of iron sulphide which is attracted by the magnet. In the closed tube a sublimate of arsenic sulphide. Gives fire with a steel and emits a garlic odor.

Diff. Resembles arsenical cobalt, but is much harder, it giving fire with steel; it differs also in yielding a magnetic globule before the blowpipe, and in not affording the reaction of cobalt with the fluxes.

Obs. Arsenopyrite is found mostly in crystalline rocks, and is commonly associated with ores of silver, lead, iron, or copper. It is abundant at Freiberg, Munzig, and elsewhere in Europe, and also in Cornwall, England.

It occurs in crystals in New Hampshire, at Franconia, Jackson, and Haverhill; in Maine, at Blue Hill Bay, Corinth, Newfield, and Thomaston; in Vermont, at Waterbury; in Massachusetts, massive at Worcester and Sterling; in Connecticut, at Chatham, Derby, and Monroe; in New Jersey, at Franklin; in New York, in Lewis, Essex County, and near Edenville and elsewhere in Orange County; in Kent, Putnam County.

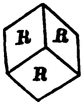
Leucopyrite. This is the name of arsenical iron Fe_2As_3. It resembles the preceding in color and in its crystals. $I \wedge I = 122° 20'$. It has less hardness and higher specific gravity. H.=5–5·5. G.=7·2–7·4. Contains Iron 32·2, arsenic 66·9, with some sulphur. From Styria, Silesia, and Carinthia.

Löllingite is another iron arsenide, $Fe\,As_2$=Arsenic 72·8, iron 27·2; specific gravity 6·8–8·71. *Berthierite* is an iron sulphantimonite.

Hematite.—Specular Iron Ore. Iron Sesquioxide.

Rhombohedral. In complex modifications of a rhombohedron of 86° 10′ (fig. 1); crystals occasionally thin tabular. Cleavage usually indistinct. Often massive granular; sometimes lamellar or micaceous. Also pulverulent and earthy.

1.



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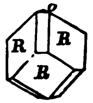

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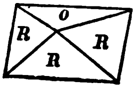


Color dark steel-gray or iron-black, and often when crystallized having a highly splendent lustre; streak-powder cherry-red or reddish-brown. The metallic varieties pass into an earthy ore of a red color, having none of the external characters of the crystals, but perfectly corresponding to them when they are pulverized, the powder they yield being of a deep red color, and earthy or without lustre. G.=4·5–5·3. Hardness of crystals 5·5–6·5. Sometimes slightly attracted by the magnet.

VARIETIES.

Specular iron. Having a perfectly metallic lustre.

Micaceous iron. Structure foliated.

Red hematite. Submetallic, or unmetallic, and of a brownish-red color.

Red ochre. Soft and earthy, and often containing clay.

Red chalk. More firm and compact than red ochre, and of a fine texture.

Jaspery clay iron. A hard impure siliceous clayey ore, and having a brownish-red jaspery look and compactness.

Clay iron stone. The same as the last, the color and appearance less like jasper. But this is one variety only of what is called "clay iron stone," a name covering also a related variety of siderite and limonite.

Lenticular argillaceous ore. A red ore, consisting of small flattened grains.

Martite is hematite in octahedrons, derived, it is supposed, from the oxidation of magnetite.

Composition. FeO^3=Oxygen 30, iron 70=100. B.B. alone infusible. Heated in the inner flame it becomes strongly magnetic.

Diff. The red powder of this mineral, and the magnetism which is so easily induced in it by a reduction flame distinguish hematite from all other ores. The word *hematite,* from the Greek *haima,* blood, alludes to the color of the powder.

Obs. This ore occurs in crystalline and stratified rocks of all ages. The more extensive beds of pure ore abound in Archæan rocks; while the argillaceous varieties occur in stratified rocks, being often abundant in coal regions and among other strata. Crystallized specimens are found also in some lavas, as a volcanic product.

Splendid crystallizations of this ore come from Elba, whose beds were known to the Romans; also from St. Gothard; Arendal, Norway; Longbanshyttan, Sweden; Lorraine and Dauphiny. Etna and Vesuvius afford handsome specimens.

In the United States, this is an abundant ore. The two Iron Mountains of Missouri, situated 90 miles south of St. Louis, consist mainly of this ore, piled "in masses of all sizes from a pigeon's egg to a middle-size church." One of them is 300 feet high, and the other, the "Pilot Knob," is 700 feet. The massive and micaceous varieties occur there together with red ochreous ore. Large beds occur in Essex, St. Lawrence and Jefferson counties, N. Y., and at Marquette, in Michigan; the micaceous variety, at Hawley, Mass., Piermont, N. H., and in Stafford County, Va.; lenticular argillaceous ore abundantly in Oneida, Herkimer, Madison and Wayne counties, N. Y., constituting one or two beds of the Clinton group (Upper Silurian), in a compact sandstone;

and the same is found in Pennsylvania and south to Alabama, and also in Wisconsin; it contains 50 per cent. of oxide of iron, with about 25 of carbonate of lime and more or less magnesia and clay. The coal region of Pennsylvania affords abundantly the clay iron ores, but they are mostly either the argillaceous carbonate or limonite.

Valuable as an iron ore, though less easily worked when pure and metallic than the magnetic and hydrous ores. Pulverized red hematite is used for polishing metal. Red chalk is a well-known material for red pencils.

Menaccanite.—Ilmenite. Titanic Iron. Washingtonite.

Rhombohedral. $R \wedge R = 85° 31'$. Often in thin plates or seams in quartz; also in grains. Crystals sometimes very large and tabular.

Color iron-black; streak submetallic. Lustre metallic or submetallic. H. = 5–6. G. = 4·5–5. Acts slightly on the magnetic needle.

Composition. Like that of hematite, except that part of the iron is replaced by titanium; the amount replaced is very variable. Infusible alone before the blowpipe.

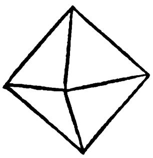
Diff. Near specular iron, but its powder is not red.

Obs. Crystals, an inch or so in diameter, occur in Warwick, Amity and Monroe, Orange County, N. Y.; also near Edenville and Greenwood Furnace; also at South Royalston and Goshen, Mass.; at Washington, South Britain, and Litchfield, Conn.; at Westerly, Rhode Island.

It is of no value in the arts and is a deleterious constituent of many iron ores.

Magnetite.—Magnetic Iron Ore.

1.



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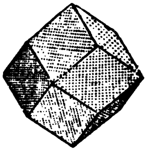


Isometric. Often in octahedrons (fig. 1), and dodecahedrons (fig. 2). Cleavage octahedral; sometimes distinct. Also granularly massive. Occasionally in dendritic forms between the folia of mica.

Color iron-black. Streak black. Brittle. H. = 5·5–6·5. G. = 5·0–5·1. Strongly attracted by the magnet, and sometimes having polarity.

Composition. $\mathrm{Fe\,\bar{Fe}\,O_4 = Fe\,O + \bar{Fe}\,O_3}$ = Oxygen 27·6, iron

72·4=100. Infusible before the blowpipe. Yields a yellow glass when fused with borax in the outer flame.

Diff. The black streak and strong magnetism distinguish this species from the following.

Obs. Magnetic iron ore occurs in extensive beds, and also in disseminated crystals. It is met with in granite, gneiss, mica schist, clay slate, syenyte, hornblende and chlorite schist; and also sometimes in limestone.

The beds at Arendal, and nearly all the Swedish iron ore, consist of massive magnetic iron. At Dannemora and the Taberg in Southern Sweden, and also in Lapland at Kurunavara and Gelivara, there are mountains composed of it.

In the United States it constitutes extensive beds, in Archæan rocks, in Warren, Essex, Clinton, Orange, Putnam, Saratoga and Herkimer counties, New York; and in Sussex and Warren counties, in New Jersey. Smaller deposits occur in the several New England States and Canada. Also found at Magnet Cove, in Arkansas; in California, in Sierra County, and elsewhere. It exists with hematite in the Iron Mountains of Missouri.

Masses of this ore, in a state of magnetic polarity, constitute what are called *lodestones* or *native magnets*. They are met with in many beds of the ore. Siberia and the Hartz have afforded fine specimens; also the Island of Elba. They also occur at Marshall's Island, Maine; also near Providence, Rhode Island, and at Magnet Cove, in Arkansas. The lodestone is called *magnes* by Pliny, from the name of the country, Magnesia (a province of ancient Lydia), where it was found; and it hence gave the terms *magnet* and *magnetism* to science.

Franklinite.

Isometric. In octahedral and dodecahedral crystals. Also coarse granular massive. Color iron-black; streak dark reddish-brown. Brittle. H.=5·5–6·5. G.=4·85–5·1. Usually is attracted by the magnet.

Composition. General formula like that of magnetite, $RR\,O_4$, but having zinc and manganese replacing part of the iron, as indicated in the formula $(Fe, Zn, Mn)\,(Fe,Mn)\,O_4$. A common variety corresponds to $Fe_2\,O_3$ 67·6, $Fe\,O$ 5·8, $Zn\,O$ 6·9, $Mn\,O$ 9·7=100.

B.B. with soda on charcoal a zinc coating is obtained; a soda bead in the outer flame is colored green by the manganese.

Diff. Resembles magnetic iron, but the exterior color is a more decided black. The streak is reddish brown, and the blowpipe reactions are distinctive.

Obs. This is an abundant ore at Sterling and Hamburg, in New Jersey, near the Franklin Furnace; at the former place the crystals are sometimes four inches in diameter; also amorphous at Altenberg, near Aix-la-Chapelle.

Chromite.—Chromic Iron.

Isometric. In octahedral crystals, without distinct cleavage. Usually massive, and breaking with a rough unpolished surface.

Color iron-black and brownish black; streak dark brown. Lustre submetallic; often faint. H.=5·5. G.=4·3–4·6. In small fragments attractable by the magnet.

Composition. General formula $\mathrm{RR}\,\mathrm{O}_4$, as for magnetite; but part of the iron is replaced by chromium. Analysis gives Iron protoxide 32, chromium sesquioxide 68=100; aluminum and magnesium also are commonly present in variable amounts, replacing the other constituents. B.B. infusible alone; with borax a beautiful green bead.

This ore usually possesses a less metallic lustre than the other black iron ores.

Obs. Occurs usually in serpentine rocks, in imbedded masses or veins. Some of the foreign localities are the Gulsen Mountains in Styria; the Shetland Islands; the department of Var in France; Silesia, Bohemia, etc.

In the United States it is abundant: in Maryland in the Bare Hills, near Baltimore, and also in Montgomery County, at Cooptown, in Harford County; and in the north part of Cecil County; occurs also in Townsend and Westfield, Vermont, and at Chester and Blandford, Mass. It is also found in Pennsylvania, at Wood's Mine, near Texas, Lancaster County, in West Branford, Chester County; at Bolton and Ham, Canada East; in California near New Idria; also in Sonoma County; Tuolumne County, near Crimea House, and elsewhere; at Seattle in Wyoming.

The compounds of chromium, which are extensively used as pigments, are obtained chiefly from this ore. Meteorites have afforded a chromium-sulphide, named *Daubréelite.*

Limonite.—Brown Hematite.

Usually massive, and often with a smooth botryoidal or stalactitic surface, having a compact fibrous structure within. Also earthy.

Color dark brown and black to ochre-yellow ; streak yellowish brown to dull yellow. Lustre sometimes submetallic ; often dull and earthy ; on a surface of fracture frequently silky. H. $=5$–$5{\cdot}5$. G. $=3{\cdot}6$–4.

The following are the principal varieties :

Brown hematite. The botryoidal, stalactitic and associated compact ore.

Brown ochre, Yellow ochre. Earthy ochreous varieties, of a brown or yellow color.

Brown and *Yellow clay iron stone.* Impure ore, hard and compact, of a brown or yellow color.

Bog iron ore. A loose earthy ore of a brownish-black color, occurring in low grounds.

Composition. $FeO_9H_6 (=2\,FeO_3+3\,H_2O)$ = Iron sesquioxide $85{\cdot}6$, water $14{\cdot}4=100$; or it is a *hydrous* iron sesquioxide, containing, when pure, about two-thirds its weight of pure iron. B.B. blackens and becomes magnetic ; with borax in the outer flame a yellow glass.

Diff. This is a much softer ore than either of the two preceding, and is peculiar in its frequent stalactitic forms, and in its affording water when heated in a glass tube.

Obs. Occurs connected with rocks of all ages, but appears, as shown by the stalactitic and other forms, to have resulted in all cases from the decomposition of other iron ores.

An abundant ore in the United States. Extensive beds exist in Salisbury and Kent, Conn., also in the neighboring towns of Beekman, Fishkill, Dover, Amenia, N. Y.; also in a similar situation north, in Richmond and West Stockbridge, Mass. ; also in Bennington, Monkton, Pittsford, Putney, and Ripton, Vermont. Large beds are found in Pennsylvania, the Carolinas, near the Missouri Iron Mountains, and also in Tennessee, Iowa and Wisconsin.

This is one of the most valuable ores of iron. The limonite of Western New England, and that along the same range geologically in Dutchess County, New York, Eastern Pennsylvania, and beyond, is remarkably free from phosphorus, and hence is highly valued for its iron. Bog ores usually contain much phosphorus, from organic sources, and hence the iron afforded is best fitted for castings. Limonite is also pulverized and used for polishing metallic buttons and other articles. As yellow ochre, it is a common material for paint.

Göthite (*Pyrrhosiderite, Lepidokrokite*) is another iron hydrate, often in prismatic crystals, as well as fibrous and massive, of the formula $Fe O_4 H_2 (= Fe O_3 + H_2 O)$, and G. = 4·0–4·4.

Turgite has the formula $Fe O_7 H_2 = 2 Fe O_3 + H_2 O$. *Xanthosiderite* and *limnite* are other related hydrates.

Melanterite.—Copperas. Iron Vitriol. Green Vitriol.

Monoclinic. In acute oblique rhombic prisms. $I \wedge I = 82° 21'$; $O \wedge I = 80° 37'$. Cleavage parallel to O perfect. Generally pulverulent or massive.

Color greenish to white. Lustre vitreous. Subtransparent to translucent. Taste astringent, sweetish, and metallic. Brittle. H. = 2. G. = 1·83.

Composition. $Fe O_4 S + 7aq$ = Sulphur trioxide 28·8, iron protoxide 25·9, water 45·3 = 100. B.B. becomes magnetic. Yields glass with borax. On exposure, becomes covered with a yellowish powder, which results from oxidation.

Obs. This species is the result of the decomposition of pyrite and pyrrhotite, which readily afford it if moistened while exposed to the atmosphere, and it is obtained from these sulphides for the arts (p. 173). An old mine near Goslar, in the Hartz, is a noted locality.

Copperas is much used by dyers and tanners, on account of its giving a black color with tannic acid, an ingredient in nutgalls and many kinds of bark. It for the same reason forms the basis of ordinary *ink*, which is essentially an infusion of nutgalls and copperas. It is also employed in the manufacture of *Prussian blue.* With potassium ferrocyanide, any soluble salt of iron sesquioxide, even in minute quantity, gives a fine blue color to the solution (due to the formation of Prussian blue), and this is a delicate test of the presence of iron.

Coquimbite, Copiapite, Voltaite, Raimondite, Botryogen, Fibroferrite, Ihleite, are names of other hydrous iron sulphates; and *Halotrichite* is an iron-alum.

Jarosite is a hydrous iron-potash sulphate.

Pisanite is an iron-copper vitriol.

Lagonite. A hydrous iron borate, from the Tuscan lagoons.

Wolframite.—Wolfram. Iron-Manganese Tungstate.

Monoclinic. Sometimes pseudomorphous in octahedrons formed by the alteration of tungstate of lime. Also massive. Color dark grayish-black; streak dark reddish-brown. Lustre submetallic, shining, or dull. H.$=5$–$5\cdot5$. G.$=7\cdot1$–$7\cdot5$.

Composition. $(Fe,Mn)O_4W$. A typical variety affords tungsten trioxide 76·47, iron protoxide 9·49, manganese protoxide 14·04$=$100. A manganese wolframite has been named *Hübnerite.* B.B. fuses easily to a magnetic globule; with aqua regia dissolved with the separation of yellow tungsten trioxide.

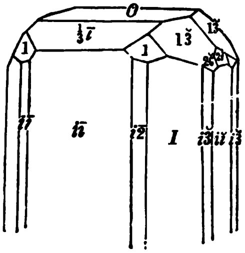
Found often with tin ores. Occurs in Cornwall, and at Zinnwald and elsewhere in Europe. In the United States it is found at Monroe and Trumbull, Conn.; on Camdage Farm, near Blue Hill Bay, Me.; near Mine la Motte, Missouri; in the gold regions of North Carolina; in Mammoth Mining district, Nevada Hübnerite.

Columbite.

Trimetric. In rectangular prisms, more or less modified. Also massive. Cleavage parallel to the lateral faces of the prism, somewhat distinct.

Color iron-black, brownish-black; often with a characteristic iridescence on a surface of fracture; streak dark brown, slightly reddish. Lustre submetallic, shining. Opaque. Brittle. H.$=5$–6. G.$=5\cdot4$–$6\cdot5$.

Composition. Iron columbate, of the formula $F\,O_6\,Cb_2$=Columbium pentoxide 79·6, iron protoxide 16·4, manganese protoxide 4·4, tin oxide 0·5, lead and copper oxides 0·1$=$100. Tantalum often replaces part of the columbium, and in this case the mineral is of higher specific gravity. B.B. alone infusible. It imparts to the borax bead the yellow color of iron.



Diff. Its dark color, submetallic lustre, and a slight iridescence, together with its breaking readily into angular fragments, will generally distinguish this species from the ores it resembles.

Obs. Occurs in granite at Bodenmais in Bavaria, and also in Bohemia. In the United States, it is found in granitic veins, at Middletown and Haddam, Conn.; at Chesterfield and Beverly, Mass.; at Acworth, N. H.; Greenfield, N. Y. A crystal was found at Middletown, which originally weighed 14 pounds avoirdupois; and a part of it, 6 inches in length and breadth, weighing 6 lbs. 12 oz., is now in the collections of the Wesleyan University of that place. Also at Standish, Maine; and in granite veins in North Carolina.

This mineral was first made known from American specimens, by Mr. Hatchett, an English chemist, and the new metal it was found to contain was named by him *columbium.*

Tantalite. $Fe(Mn)O_6Ta_2$. This tantalate of iron is allied to columbite. H. 6–6·5. G. 7–8. It is distinguished by its higher specific gravity. It sometimes contains tin and tungsten. From Finland, Sweden, near Limoges in France, and from North Carolina and Alabama.

Note.—The metal named *Columbium* by Hatchett, is the same that has since been called *Niobium,* without any good reason for the change of name.

Triphylite. An iron manganese-lithium phosphate. See p. 190.

Vivianite.—Hydrous Iron Phosphate.

Monoclinic. In modified oblique prisms, with cleavage in one direction highly perfect. Also radiated, reniform, and globular, or as coatings.

Color deep blue to green. Crystals usually green at right angles with the vertical axis, and blue parallel to it. Streak bluish. Lustre pearly to vitreous. Transparent to translucent; opaque on exposure. Thin laminæ flexible. H.= 1·5–2. G.=2·66.

Composition. $Fe_3O_8P_2+8aq$ = Phosphorus pentoxide, 28·3, iron protoxide 43·0, water 28·7=100. B.B. fuses easily to a magnetic globule, coloring the flame greenish blue. Affords water in a glass tube, and dissolves in hydrochloric acid.

Diff. The deep blue color and the little hardness are decisive characteristics. The blowpipe affords confirmatory tests.

Obs. Found with iron, copper and tin ores, and sometimes in clay, or with bog iron ore. St. Agnes in Cornwall, Bodenmais, and the gold mines of Vöröspatak in Transylvania, afford fine crystallizations. In the United States, good crystals have been found at Imlaystown, N. J. At Allentown, Monmouth County, and Mullica Hill, Gloucester County, N. J., are other localities. It often fills the interior of certain fossils. Occurs also at Harlem, N. Y., in Somerset and Worcester counties, Md., and with bog ore in Stafford County, Va. Abundant at Vandreuil in Canada, where it is associated with limonite.

The *blue iron earth* is an earthy variety, containing about 30 per cent. of phosphoric acid.

Ludlamite. A clear green hydrous phosphate of iron in monoclinic crystals; from Cornwall.

Dufrenite. A hydrous phosphate of iron sesquioxide. It has a dull green color, and is often found in radiated forms.

Cacoxenite. Occurs in radiated silky tufts of a yellow or yellowish-brown color. H.=3-4. G.=3·38. It is a phosphate of iron sesquioxide, and often contains alumina. It differs from wavellite, which it resembles, in its more yellow color and iron reactions. It also resembles carpholite, but has a deeper color, and does not give the manganese reactions. It occurs on brown iron ore in Bohemia.

Chalcosiderite and *Andrewsite* are other iron phosphates.

Strengite. A hydrous iron phosphate related in formula to scorodite. From near Giessen.

Arsenates of Iron.

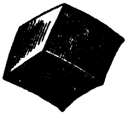
Pharmacosiderite, or *Cube ore*. Occurs in cubes of dark green to brown and red colors. Lustre adamantine, not very distinct. Streak greenish or brownish. H.=2·5. G.=3. It is a hydrous arsenate of iron sesquioxide, containing 43 per cent. of arsenic pentoxide. From the Cornwall mines; also from France and Saxony.

Scorodite. Crystallizes in rhombic prisms, with an angle of 120° 10′ between its secondary prismatic planes. Color pale leek-green or liver brown. Streak uncolored. Lustre vitreous to subadamantine. Subtransparent to nearly opaque. H.=3·5-4. G.=3·1-3·3. A hydrous arsenate of iron sesquioxide, containing 50 per cent. of arsenic pentoxide. From Saxony, Carinthia, Cornwall, and Brazil; and minute crystals near Edenville, N. Y., with arsenical pyrites. The name of this species is from the Greek *skorodon*, garlic, alluding to the odor before the blowpipe. *Iron sinter* is an amorphous form of the same mineral.

Arseniosiderite is another iron arsenate.

Siderite.—Spathic Iron. Iron Carbonate.

Rhombohedral. In rhombohedrons with easy cleavage parallel to a rhombohedron of 107°. Faces often curved. Usually massive, with a foliated structure, somewhat curving. Sometimes in globular concretions or implanted globules.



Color light grayish to brown; often dark brownish-red. It becomes nearly black on exposure. Streak uncolored. Lustre pearly to vitreous. Translucent to nearly opaque. H. =3–4·5. G. =3·7–3·9.

Composition. FeO_3C=Carbon dioxide 37·9, iron protoxide 62·1=100. Often contains some manganese oxide or magnesia, and lime replacing part of the iron protoxide. Before the blowpipe it blackens and becomes magnetic; but alone it is infusible. Dissolves in heated hydrochloric acid with effervescence.

The ordinary crystallized or foliated variety is called *spathic* or *sparry* iron, because the mineral has the aspect of a spar. The globular concretions found in some amygdaloidal rocks have been called *spherosiderite* because of its *spheroidal* forms. An argillaceous variety occurring in nodular forms is often called *clay iron stone,* and is abundant in coal measures.

Diff. This mineral cleaves like calcite and dolomite, but it has a much higher specific gravity. It readily becomes magnetic before the blowpipe. Heated in a closed glass tube it gives off carbon dioxide, and becomes magnetic. This test distinguishes it from other iron ores.

Obs. Spathic iron occurs in rocks of various ages, and often accompanies metallic ores. The largest deposits are in gneiss and mica schist, and clay slate. It is also abundant in the coal formation principally in the form of clay iron stone. In Styria and Carinthia, it is very abundant in gneiss, and in the Hartz it occurs in graywacke. Cornwall, Alstonmoor, and Devonshire are English localities.

A vein of considerable extent occurs at Roxbury, near New Milford, Conn., in quartz, traversing gneiss; at Plymouth, Vt., and Sterling, Mass., it is also abundant. It occurs also at Monroe, Conn.; in New York State, in Antwerp, Jefferson County, and in Hermon, St. Lawrence County. The argillaceous carbonate in nodules and beds, is very abundant in the coal regions of Pennsylvania and the West.

This ore is employed extensively for the manufacture of iron and steel.

Mesitite is an iron-and-magnesium carbonate. *Ankerite* contains in addition a large percentage of calcium. Like siderite in crystallization and cleavage.

General Remarks.—The metal iron has been known from the most remote historical period, but was little used until the last centuries before the Christian era. Bronze, an alloy of copper and tin, was the almost universal substitute, for cutting instruments as well as weapons of war, among the ancient Egyptians and earlier Greeks; and even among the Romans (as proved by the relics from Pompeii), and also throughout Europe, it continued long to be extensively employed for these purposes.

The *Chalybes*, bordering on the Black Sea, were workers in iron and steel at an early period; and near the year 500 B.C., this metal was introduced from that region into Greece, so as to become common for weapons of war. From this source we have the expression *chalybeate* applied to certain substances or waters containing iron.

The iron mines of Spain have also been known from a remote epoch, and it is supposed that they have been worked "at least ever since the times of the later Jewish kings; first by the Tyrians, next by the Carthaginians, then by the Romans, and lastly by the natives of the country." These mines are mostly contained in the present provinces of New Castile and Aragon. Elba was another region of ancient works, "inexhaustible in its iron," as Pliny states, who enters somewhat fully into the modes of manufacture. The mines are said to have yielded iron since the time of Alexander of Macedon. The ore beds of Styria in Lower Austria, were also a source of iron to the Romans.

The ores from which the iron of commerce is obtained, are the spathic iron or carbonate, magnetic iron, hematite or specular iron, limonite or "brown hematite," and bog iron ore. In England, the principal ore used is an argillaceous carbonate of iron, called often clay iron stone, found in nodules and layers in the coal measures. It consists of carbonate of iron, with some clay, and externally has an earthy, stony look, with little indication of the iron it contains except in its weight. It yields from 20 to 35 per cent. of cast iron. The coal basin of South Wales, and the counties of Stafford, Salop, York, and Derby, yield by far the greater part of the English iron. Brown hematite is also extensively worked. In Sweden and Norway, at the famous works of Dannemora and Arendal, the ore is the magnetic iron ore, and is nearly free from impurities as it is quarried out. It yields 50 to 60 per cent. of iron. The same ore is worked in Russia, where it abounds in the Urals. The Elba ore is the specular iron. In Germany, Styria, and Carinthia, extensive beds of the spathic iron are worked. The bog ore is largely reduced in Prussia.

In the United States, all these different ores are worked. The localities are already mentioned. The magnetic ore is reduced in New England, New York, Northern New Jersey, and sparingly in Pennsylvania, and other States. Limonite, or brown hematite, is largely worked along Western New England and Eastern New York, in Pennsylvania, and many States South and West. The earthy argillaceous carbonate like that of England, and the hydrate, are found with the coal deposits, and are a source of much iron.

The amount of iron manufactured in the world in the year 1873 was 14,885,488 tons, of which Great Britain produced 6,566,000 tons, United States, 2,561,000 tons, Germany 1,665,000 tons, France 1,381,000 tons, Belgium 653,000 tons, Austria with Hungary 425,000 tons, Russia 354,000 tons, Sweden 322,000 tons, Luxembourg 300,000 tons.

MANGANESE.

The common ores of manganese are the oxides, the carbonate, and the silicates. There are also sulphides, an arsenide, and phosphate. They have a specific gravity below 5·2.

Manganese Sulphides and Arsenide.

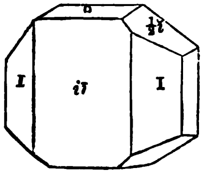
Alabandite or *Manganblende.* A manganese sulphide MnS, of an iron-black color, green streak, submetallic lustre. H.=3·5–4. G.=3·9–4·0. Crystals, cubes and regular octahedrons. From the gold mines of Nagyag, in Transylvania.

Hauerite. A sulphide, MnS^2, containing twice the proportion of sulphur in the last. Color reddish brown and brownish black, resembling blende. H.=4. G.−3·46. From Hungary.

Kaneite is a manganese arsenide, of a grayish-white color, and metallic lustre, which gives off alliaceous fumes. G.=5·55. From Saxony.

Pyrolusite.—Manganese Dioxide.

Trimetric. In small rectangular prisms, more or less modified. $I \wedge I = 93° 40'$. Sometimes fibrous and radiated or divergent. Often massive and in reniform coatings.



Color iron-black; streak black, nonmetallic. H.=2–2·5 G.=4·8.

Composition. MnO_2 = Manganese 63·2, oxygen 36·8=100. A minute portion of it imparts to a borax bead a deep amethystine color while hot, which becomes red-brown on cooling. It yields no water in a matrass.

Diff. Differs from psilomelane by its inferior hardness, and from ores of iron by the violet glass with borax.

Obs. This ore is extensively worked in Thuringia, Moravia, and Prussia. It is common in Devonshire and Somersetshire, in England, and in Aberdeenshire. In the United States it is associated with the following species in Vermont, at Bennington, Brandon, Monkton, Chittenden, and Irasburg; it occurs also in Maine, at Conway, and Plainfield in Massachusetts; at Salisbury and Kent, in Conn., on hematite; on Red Island, in the Bay of San Francisco; at Pictou and Walton, Nova Scotia; near Bathurst, in New Brunswick.

The name *pyrolusite* is from the Greek *pur*, fire, and *luo*, to wash, and alludes to its property of discharging the brown and green tints of glass, for which it is extensively used.

Besides the use just alluded to, this ore is extensively employed for bleaching, and for affording the gas oxygen to the chemist.

Hausmannite. A manganese oxide, $2MnO+MnO_2$, which contains 72·1 per cent. of manganese, when pure. Brownish black and submetallic, occurring massive and in square octahedrons. H.=5–5·5. G.=4·7. From Thuringia and Alsatia. *Hetærolite* is a zinc-hausmannite, from Sterling Hill, N. J.

Braunite. An oxide of manganese, containing 69 per cent. of manganese when pure. Color and streak dark brownish-black, and lustre submetallic. Occurs in square octahedrons and massive. H.=6–6·5. G.=4·8. From Piedmont and Thuringia.

Manganite. A hydrous sesquioxide of manganese. Occurs massive and in rhombic prisms. Color steel-black to iron-black. H.=4–4·5. G.=4·3–4·4. From the Hartz, Bohemia, Saxony, and Aberdeenshire. It is found at several points in New Brunswick and Nova Scotia.

Psilomelane.

Massive and botryoidal. Color black or greenish-black. Streak reddish or brownish-black, shining. H.=5–6. G.=4–4·4.

Composition. Essentially manganese dioxide with a little water, and also some baryta or potassa. The compound is somewhat varying in its constitution. Before the blowpipe like pyrolusite, except that it affords water.

Obs. This is an abundant ore, and is associated usually with the pyrolusite. It occurs at the different localities mentioned under pyrolusite, and the two are often in alternating layers; it has been considered an impure variety of the pyrolusite. The name is from the Greek *psilos*, smooth or naked, and *melas*, black.

Pyrochroite. Hydrous manganese protoxide, of white color. From Sweden. MnO_2H_2.

Pelagite. The manganese nodules found in many regions over the bottom of the ocean. Affords, according to an analysis, about 40 per cent. of MnO_2, 27 FeO_3, 13 of water lost at a red heat, along with 14 per cent. of silica and 4 of alumina; 24·5 per cent. of water were lost below 100° C. Probably a mixture.

Chalcophanite. A hydrous oxide of manganese and zinc, in rhombohedral crystals and stalactites; from Sterling Hill, N. J.

Wad.—Bog Manganese.

Massive, reniform or earthy ; also in coatings and dendritic delineations. Color and streak black or brownish black. Lustre dull, earthy. H.=1–6. G.=3–4. Soils the fingers.

Composition. Consists of manganese dioxide, in varying proportions, from 30 to 70 per cent., mechanically mixed with more or less of iron sesquioxide, 10 to 25 per cent. of water, and often several per cent. of oxide of cobalt or copper. It is formed in low places from the decomposition of minerals containing manganese. Gives off much water when heated, and affords a violet glass with borax.

Obs. Wad is abundant in Columbia and Dutchess counties, N. Y., at Austerlitz, Canaan Centre, and elsewhere; also at Blue Hill Bay, Dover, and other places in Maine; at Nelson, Gilmanton, and Grafton, N. H.; and in many other parts of the country.

It may be employed like the preceding in bleaching, but is too impure to afford good oxygen. It may also be used for umber paint.

Lampadite, or Cupreous Manganese. A wad containing 4 to 18 per cent. of copper oxide.

Triphylite.

Trimetric. In rhombic crystals, massive. Color greenish gray to bluish gray, but often brownish black externally from the oxidation of the manganese present. Streak grayish white. Lustre subresinous. H.=5. G.=3·54–3·6.

Composition. $(\frac{1}{4}Li_2\,\frac{3}{4}R)_3\,O_8\,P_2$, in which R stands for Fe and Mn. A Bodenmais specimen afforded Phosphorus pentoxide 44·19, iron protoxide 38·21, manganese protoxide 5·63, magnesia 2·39, lime 0·76, lithia 7·69, soda 0·74, potash 0·04, silica 0·40=100·05. B.B. fuses very easily, coloring the flame a beautiful red, in streaks, with a pale bluish-green on the exterior of the flame. Soluble in hydrochloric acid.

Obs. Found at Rabenstein in Bavaria; in Finland; at Norwich, Mass.; Grafton, N. H.

Lithiophilite. A salmon-colored manganese-lithium phosphate, allied in composition to triphylite, but containing very little iron. From Redding (near Branchville Depot), Conn.

Triplite.

Trimetric. Usually massive, with cleavage in three directions. Color blackish brown. Streak yellowish gray. Lustre resinous; nearly or quite opaque. H.=5–5·5. G.=3·4–3·8.

Composition. $(Mn,Fe)_3O_8P_2+RF_2$, affording about 30 per cent. of manganese protoxide, 8 of fluorine. Fuses easily to a black magnetic globule. B.B. imparts a violet color to the hot borax bead. Dissolves in hydrochloric acid.

Obs. From Limoges in France. Rather abundant at Washington, Conn., and sparingly found at Sterling, Mass.

Heterosite, Alluaudite, Pseudotriplite, are regarded as results of alteration, either of triphyline or of triplite.

Triploidite. A manganese-iron phosphate like triplite, but having the fluorine replaced by the elements of water. From Redding, Conn.

Dickinsonite. An oil-green to olive-green manganese-iron-calcium phosphate. From Redding, Conn.

Reddingite. A rose-pink hydrous manganese-iron phosphate. $Mn_3 O_8 P_2+3$ aq, isomorphous with scorodite and strengite. Redding, Ct.

Fairfieldite, hydrous manganese-calcium phosphate. Ibid.

Hureaulite. Rose-colored to brownish-orange hydrous manganese-iron phosphate. From Hureaux, France.

Rhodochrosite.—Manganese Carbonate.

Rhombohedral. $R \wedge R = 166° 51'$; like calcite in having three easy cleavages, and in lustre. Color rose-red. H.=3·5–4·5. G.=3·4–3·7.

Composition. $Mn\,O_3\,C$=Carbonic acid 38·6, manganese protoxide 61·4=100. Part of the manganese often replaced by calcium, magnesium or iron.

Obs. From Saxony, Transylvania, the Hartz, Ireland; Mine Hill, New Jersey; Redding, Conn.; Austin, Nevada; Placentia Bay, Newfoundland.

Rhodonite. A manganese silicate. See p. 247

General Remarks. Manganese is never used in the arts in the pure state; but as an oxide it is largely employed in bleaching. The importance of the ore for this purpose depends on the oxygen it contains, and the facility with which this gas is given up. As the ores are often impure, it is important to ascertain their value in this respect. This is most readily done by heating gently the pulverized ore with hydrochloric acid, and ascertaining the amount of chlorine given off. The chlorine may be made to pass into milk of lime, to form a chloride, and the value of the chloride then tested according to the usual modes. The amount of chlorine derived from a given quantity of muriatic acid depends not only on the amount of oxygen in the ore, but also on the presence or absence of baryta and such other earths as may combine with this acid. The binoxide of manganese, when pure, affords 18 parts by weight of chlorine, to 22 parts of the oxide; or 23½ cubic inches of gas from 22 grains of the oxide. The best ore should give about three-fourths its weight of chlorine, or about 7,000 cubic inches to the pound avoirdupois.

Iron ores containing some manganese are used for making *spiegeleisen*, a hard highly crystallized pig-iron, containing a large amount of carbon and some manganese. A manganesian iron carbonate or siderite is thus used, and also the franklinite of New Jersey.

Manganese is also employed to give a violet color to glass. The sulphate and the chloride of manganese are used in calico printing. The sulphate gives a chocolate or bronze color.

ALUMINUM.

The aluminum compounds among minerals include only one oxide—a sesquioxide $\ddot{A}l\,O_3$—hydrated oxides, fluorides, and, among ternaries, sulphates, phosphates, and numerous silicates. There are no sulphides or arsenides, and no carbonate, with a single imperfectly understood exception.

The silicates are described in the following section. Many aluminum compounds may be distinguished by means of a blowpipe experiment, as explained on page 87.

Corundum.

Rhombohedral. $R \wedge R$ or $r \wedge r = 86° 4'$. Cleavage sometimes perfect parallel with *O*, and sometimes parallel to the rhombohedral faces. Usual in six-sided prisms, often with uneven surfaces, and sometimes so irregular that the form is scarcely traceable. Occurs also granular. Colors blue, and grayish-blue most common; also red, yellow, brown, and nearly black; often bright. When polished on the surface *O*, a star of six rays, corresponding with the six-sided form of the prism, is sometimes seen within the crystal. Transparent to translucent. H.=9, or next below the diamond. Exceedingly tough when compact. G.=3·9–4·16.

Composition. $\ddot{A}l\,O_3$=Oxygen 46·8, aluminum 53·2=100; pure alumina. B.B. remains unaltered both alone and with soda. The fine powder moistened with cobalt nitrate and ignited assumes a blue color.

VARIETIES. The name *sapphire* is usually restricted, in common language, to clear crystals of bright colors, used as gems; while dull, dingy-colored crystals and masses are called *corundum,* and the granular variety of bluish-gray and blackish colors containing much disseminated magnetite (whence its dark color) is called *emery.*

Blue is the true sapphire color. When of other bright tints, it receives other names; as *oriental ruby,* when red; *oriental topaz,* when yellow; *oriental emerald,* when green; *oriental amethyst,* when violet, and *adamantine spar,* when hair-brown. Crystals with a radiate chatoyant interior are often very beautiful, and are called *asteria,* or *asteriated sapphire.*

Diff. Distinguished readily by its hardness, exceeding all species except the diamond, and scratching quartz crystals with great facility.

Obs. The sapphire is often found loose in the soil. Metamorphic rocks, especially gneissoid mica schist, and granular limestone, appear to be its usual matrix. It is met with in several localities in the United States, but seldom sufficiently fine for a gem. A blue variety occurs at Newton, N. J., in crystals sometimes several inches long; bluish and pink, at Warwick, N. Y.; white, blue, and reddish crystals at Amity, N. Y.; grayish, in large crystals, in Delaware and Chester counties, Pennsylvania; pale blue crystals have been found in bowlders at West Farms and Litchfield, Conn. It occurs also in large quantities in North Carolina, where crystals are numerous though rarely fit for jewelry, and where one has been obtained weighing 312 pounds, and having a reddish color outside and bluish-gray within; also in Cherokee County, Georgia; in Los Angeles County, California. Emery is mined at Chester, in Mass.

The principal foreign localities are as follows: blue, from Ceylon; the finest red from the Capelan Mountains in the kingdom of Ava, and smaller crystals from Saxony, Bohemia and Auvergne; corundum, from the Carnatic, on the Malabar coast, and elsewhere in the East Indies; adamantine spar, from the Malabar coast; emery, in large bowlders from near Smyrna, and also at Naxos and several of the Grecian islands.

The name sapphire is from the Greek word *sappheiros,* the name of a blue gem. It is doubted whether it included the sapphire of the present day.

Next to the diamond, the sapphire in some of its varieties is the most costly of gems. The red sapphire is much more highly esteemed than those of other colors. A crystal of one, two or three carats is valued at the price of a diamond of the same size. They seldom exceed half an inch in their dimensions. Two splendid red crystals, as long as the little finger and about an inch in diameter, are said to be in the possession of the king of Arracan. The largest oriental ruby known was brought from China to Prince Gargarin, governor of Siberia; it afterward came into the possession of Prince Menzikoff, and constitutes now a jewel in the imperial crown of Russia.

Blue sapphires occur of much larger size. According to Allan, Sir Abram Hume possessed a crystal which was three inches long. One of 9·51 carats is stated to have been found in Ava.

Corundum and emery are crushed to a powder of different degrees of fineness, and make the abrading and polishing material called in the shops *emery*. The iron oxide of true emery diminishes its hardness, and consequently its abrasive power; pulverized corundum is more valuable and efficient in abrasion.

Diaspore. Hydrated aluminum of the formula $Al\,O_4\,H_2$=Water 14·9, alumina 85·1=100. Usually found associated with corundum. Crystals usually thin and flattened. Color whitish, grayish, pinkish, etc. Very brittle. Translucent. H. 6·5–7. G. 3·5. From the Urals; Schemnitz; Chester, Mass.; Chester County, Pa.; North Carolina.

Gibbsite (*Hydrargillite*). Hydrated alumina; $Al\,O_6\,H_6$=water 34·5, alumina 65·5=100. Occurs in hexagonal crystals; more commonly in stalactitic and mammillary forms, with smooth surface, looking like chalcedony. Color white, grayish and greenish-white; translucent, sometimes transparent when in crystals. H.=2·5–3·5; G.=2·3–2·4. Near Slatoust in the Ural; in Asia Minor; on corundum at Unionville, Pa.; at Richmond, Mass. in stalactitic forms; in Orange County, N. Y.

Hydrotalcite (*Völknerite, Houghite*). A soft pearly mineral, containing alumina, magnesia, and water. Accompanies spinel, and sometimes a result of the alteration of spinel crystals. Occurs near Slatoust; at Snarum, Norway; near Oxbow in Rossie, St. Lawrence County, N. Y. (the variety *Houghite*).

Spinel.

Isometric. In octahedrons, more or less modified. Figure 4 represents a twin crystal. Occurs only in crystals; cleavage octahedral, but difficult.

Color red, passing into blue, green, yellow, brown, and black. The red shades often transparent and bright; the dark shades usually opaque. Lustre vitreous. H.=8. G.=3·5–4·1.

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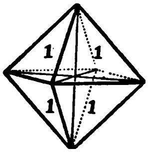

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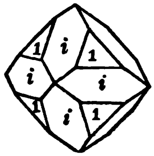

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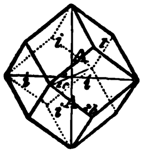

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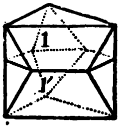

Composition. $MgAl\,O_4 = Mg\,O + AlO_3$=Alumina 72, magnesia 28=100. The aluminum is sometimes replaced in part by iron, and the magnesium often in part by iron, calcium, manganese and zinc. Infusible; insoluble in acids.

VARIETIES. The following varieties of this species have received distinct names: the scarlet or bright red crystals, *spinel ruby;* the rose-red, *balas-ruby;* the orange-red, *rubicelle;* the violet, *almandine-ruby;* the green, *chlorospinel;* while the black varieties are called *pleonaste.* Pleonaste crystals contain sometimes 8 to 20 per cent. of oxide of iron. *Picotite* is a variety containing 7 per cent. of chromium oxide.

Diff. The form of the crystals and their hardness distinguish the species. Garnet is fusible. Magnetite is attracted by the magnet. Zircon has a higher specific gravity and is not so hard. The red crystals often resemble the true ruby (red corundum), but the latter are never in octahedrons.

Obs. Occurs in granular limestone; also in gneiss and volcanic rocks. At numerous places in the adjoining counties of Sussex in New Jersey, and Orange county, of various colors from red to brown and black; especially at Franklin, Newton and Sparta, in the former, and in Warwick, Amity and Edenville, in the latter. The crystals are octahedrons, and often grouped or disseminated singly in granular limestone. One crystal, found at Amity by Dr. Heron, weighs 49 pounds. The limestone quarries of Bolton, Boxborough, Chelmsford and Littleton, Mass., afford a few crystals.

Crystals of spinel are occasionally soft, having undergone a change of composition approaching steatite in all characters except form. They are true *pseudomorphs*. They are met with in Sussex and Orange counties. Other spinel pseudomorphs consist of hydrotalcite (see preceding page).

Uses. The fine colored spinels are much used as gems. The red is the common ruby of jewelry, the *oriental* rubies being sapphire.

Gahnite is a spinel in which zinc takes the place of part or all of the magnesium; when all, it is called *Automolite*. Color dark green or greenish black. H.=7·5–8. G.=4–4·6. When fused with sufficient soda, B.B. on coal a white coat of zinc oxide is deposited, which is yellow when hot. B.B. infusible. At Franklin, N. J., and at the Canton mine in Georgia. Occurs in granite at Haddam with beryl, chrysoberyl, garnet, etc. In Sweden, near Fahlun, in talcose slate.

Dysluite. A variety of gahnite containing oxide of manganese. Color yellowish or grayish-brown. H.=7·5-8. G.=4·55. *Composition*, Alumina 30·5, zinc oxide 16·8, iron sesquioxide 41·9, manganese protoxide 7·6, silica 3, water 0·4. From Sterling, N. J., with franklinite and troostite.

Kreittonite is a zinc-iron gahnite.

Hercinite is a spinel affording on analysis alumina and iron protoxide, with only 2·9 per cent. of magnesia.

Chrysoberyl.

Trimetric. $I \wedge I = 129° 38'$. Also in compound crystals, as in fig. 2. Crystals sometimes thick; often tabular.

Color bright green, from a light shade to emerald-green; rarely raspberry or columbine-red by transmitted light. Streak uncolored. Lustre vitreous. Transparent to translucent. H.=8·5. G.=3·5–3·8.

Composition. $BeAl\,O_4$ = Alumina 80·2, glucina 19·8=100. A little iron is sometimes present. B.B. infusible and unaltered.

Alexandrite is an emerald-green variety from the Urals, colored by chrome, bearing the same relation to ordinary chrysoberyl as emerald to beryl. Fig. 7 is of this variety.

Diff. Near beryl, but distinct in not being regularly hexagonal in crystallization.

Obs. Chrysoberyl occurs in the United States in granite at Haddam, Conn., and Greenfield, near Saratoga, N. Y., associated with beryl, garnet, etc.; in Norway, Maine.

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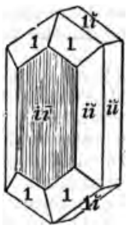

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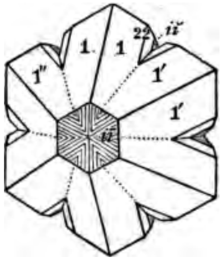


The name chrysoberyl is from the Greek *chrysos*, golden, and *beryllos*, beryl.

The crystals are seldom sufficiently pellucid and clear from flaws to be valued in jewelry; but when of fine quality, it forms a beautiful gem, and is often opalescent.

Fluorides of Aluminum.

Cryolite. In snow-white masses, having rectangular cleavages, and remarkable for melting easily in the flame of a candle, to which its name (from the Greek *kruos, ice*) alludes. H.=2·5. G.=2·95. It is a sodium-aluminum fluoride. From Greenland.

Chiolite and *Chodneffite* are near cryolite in composition and characters. *Arksutite, Gearksutite, Pachnolite, Thomsenolite* are related fluorine compounds which occur associated with the Greenland cryolite. From Siberia.

Fluellite. From Cornwall, in minute white rhombic octahedrons. Contains fluorine and aluminum.

Alunogen.—Hydrous Aluminum Sulphate.

In silky efflorescences, and crusts of a white color, having a taste like common alum. H.=1·5–2. G.=1·6–1·8.

Composition. $Al\,O_{12}\,S_3+18aq$ = Sulphur trioxide 36·0, alumina 15·4, water 48·6=100.

Obs. A common efflorescence in solfataras of volcanic regions, and also often occurring in shales of coal regions and other rocks containing pyrite; the oxidation of the pyrite—an iron sulphide—affords sulphuric acid, which acid combines with the alumina of the shale.

Alums Frequently the sulphuric acid resulting from the oxidation of a sulphide, or in some other way, combines also with the iron, magnesia or potash or soda of the shale or other rock, as well as the alumina, and so makes other kinds of aluminum sulphate.

Combining thus with potash it produces common alum called *Kalinite* or *potash alum*, whose formula is $K_2Al_2 O_{24} S_4 + 18$ aq ; with ammonia, it forms an *ammonia-alum*, named *Tschermigite ;* with iron, iron-alum, called *Halotrichite ;* with soda, a soda-alum, *Mendozite ;* with magnesia a magnesia-alum, *Pickeringite ;* with manganese, a manganese-alum, *Apjohnite* and *Bosjemanite*. The formulas of these alums are alike in atomic proportions, excepting in the amount of water, which varies from 18 aq to 24 aq.

Shale containing alunogen or any of the alums is often called *alum shale*. Such rocks, whether shales or of other kinds, are often quarried and lixiviated for the alum they contain or will afford. The rock is first slowly heated after piling it in heaps, in order to decompose the remaining pyrites and transfer the sulphuric acid of any iron sulphate to the alumina and thus produce the largest amount possible of aluminum sulphate. It is next lixiviated in stone cisterns. The lye containing this sulphate is afterwards concentrated by evaporation, and then the requisite proportion of potassium in the form of the sulphate or chloride is added to the hot solution. On cooling, the alum crystallizes out, and is afterwards washed and re-crystallized. The mother liquor left after the precipitation is revaporated to obtain the remaining alum held in solution. This process is carried on extensively in Germany, France, at Whitby in Yorkshire, Hurlett and Campsie, near Glasgow, in Scotland. Cape Sable in Maryland affords large quantities of alum annually. The slates of coal beds are often used to advantage in this manufacture, owing to the decomposing pyrites present. At Whitby, 130 tons of calcined schist give one ton of alum. In France, ammoniacal salts are used instead of potash, and an ammonia alum is formed.

Alum is also manufactured from cryolite (see p. 197), which is obtained from Greenland.

Alunite.—Alum Stone.

Rhombohedral, with perfect basal cleavage. Also massive. Color white, grayish, or reddish. Lustre of crystals vitreous, or a little pearly on the basal plane. Transparent to translucent. H. =4. G.=2·58–2·75.

Composition. $K_2 Al O_{22} S_4+6$ aq=Sulphuric trioxide 38·5, alumina 37·1, potash 11·4, water 13·0=100. B.B. decrepitates and is infusible ; gives reaction for sulphur.

Diff. Distinguished by its infusibility, in connection with its complete solubility in sulphuric acid without forming a jelly.

Obs. Found in rocks of volcanic origin at Tolfa, near Rome ; and also at Beregh and elsewhere in Hungary.

When it is calcined the sulphates become soluble, and the alum is dissolved out. On evaporation the alum crystallizes from the fluid in cubic crystals. This is called Roman alum, and is highly valued by dyers, because, although the crystals are colored red by iron oxide, no iron is chemically combined with the salt as is usual in common alum.

Aluminite (*Websterite*). Another hydrous aluminum sulphate, in compact reniform masses, and tasteless. From New Haven, in Sussex; Epernay, in France; and Halle, in Prussia.

Lœwigite is a potassium-aluminum sulphate, containing half the water of potash alum.

Amblygonite.—Lithium-Aluminum Phosphate.

Triclinic, with cleavages unequal in two directions, making an angle with one another of 104½°. Lustre vitreous to pearly and greasy. Color pale mountain-green, or sea-green to white. Translucent to subtransparent. H.=6. G.=3–3·11.

Composition. A lithium-aluminum phosphate, $Al\,O_8\,P_2 + 1\frac{1}{2}\,(Li, Na)\,F$. B.B. fuses very easily with intumescence, coloring the flame yellowish red to rich carmine-red, owing to the lithia present, and traces of green owing to the phosphoric acid. Gives the reaction also for fluorine.

Obs. Occurs in Saxony and Norway.

Hebronite is a closely related mineral from Hebron and Mount Mica in Maine, and from Redding in Connecticut.

Herderite is supposed to be an anhydrous calcium-aluminum phosphate with fluorine.

Durangite. An anhydrous arsenate of an orange-red color, containing aluminum, sodium, iron, and some manganese, with over 7 per cent. of fluorine. From Durango, Mexico, where it occurs with cassiterite or tin ore.

Lazulite.

Monoclinic. In crystals and also massive, of an azure-blue color. H.=5–6. G.=3·057.

Composition. $RAl\,O_9\,P_2 + aq$ = Phosphorus pentoxide 46·8, alumina 34·0, magnesia 13·2, water 6·0=100. B.B. in the closed tube whitens and yields water; with cobalt solution the color is restored; in the forceps whitens, swells, cracks, and falls to pieces without fusion, coloring the flame bluish-green.

Obs. From Salzburg, Styria; Wermland, Sweden; Crowder Mount, Lincoln County, N. C.; and on Graves Mountain, Lincoln County, Georgia.

Variscite (*Peganite, Callainite*) is another hydrous aluminum phosphate; it is of a light green color, of various shades, to deep emerald-green. From Montgomery County, Arkansas, and from Colorado; also from Messbach, in Saxon Voigtland. *Fischerite* is a related mineral.

Turquois.

In opaque reniform masses without cleavage; of a bluish-green color, and somewhat waxy lustre. H.=6. G.=2·6–2·8.

Composition. Phosphorus pentoxide 32·6, alumina 46·9, water 20·5=100. B.B. infusible, but becomes brown and colors the flame green; soluble in hydrochloric acid; moistened with the acid it gives a momentary bluish green color to the flame, owing to the copper that it contains.

Diff. Distinguished from bluish-green feldspar, which it resembles, by its infusibility and the reactions for phosphorus.

Obs. Turquois is brought from a mountainous district in Persia, not far from Nichabour; and, according to Agaphi, occurs in veins that traverse the mountain in every direction.

The *Callais* of Pliny was probably turquois. Pliny, in his description of it, mentions the fable that it was found in Asia, projecting from the surface of inaccessible rocks, whence it was obtained by means of slings.

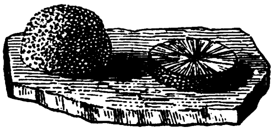
Turquois receives a fine polish and is highly esteemed as a gem. In Persia it is much admired, and the Persian king is said to retain for himself all the large and more finely tinted specimens. The *occidental* or *bone* turquois, is fossil teeth or bones, colored with a little phosphate of iron. Green *malachite* is sometimes substituted for turquois, but it is of little hardness and has a different tint of color. The stone is so well imitated by art as scarcely to be detected except by chemical tests. The imitation is much softer than true turquois.

Childrenite. A hydrous phosphate containing aluminum, iron, with little manganese. Found in trimetric crystals in Devonshire and Cornwall; also at Hebron in Maine.

Eosphorite. Has the crystalline form and nearly the angles of childrenite, and contains the same constituents, but differs in being essentially a hydrous phosphate of manganese with *little iron.* From Redding, Connecticut.

Henwoodite is a hydrous aluminum phosphate from Cornwall, containing also copper.

Wavellite.



Trimetric. Usually in small hemispheres a third or half an inch across, attached to the surface of rocks, and having a finely radiated structure within; when broken off they leave a stellate circle on the rock. Sometimes in rhombic crystals.

Color white, green, or yellowish and brownish, with a somewhat pearly or resinous lustre. Sometimes gray or black. Translucent. H.=3·5–4. G.=2·3.

Composition. $Al_3O_{19}P_4+12aq$ = Phosphorus pentoxide 35·16, alumina 38·10, water 26·74=100. 1 to 2 per cent. of fluorine is often present, replacing the oxygen. B.B. whitens and swells, but does not fuse. Colors the flame green, especially if previously moistened with sulphuric acid. Moistened with cobalt nitrate, assumes a blue color after ignition; gives much water in the closed glass tube.

Diff. Distinguished from the zeolites, some of which it resembles, by giving the reaction of phosphorus, and also by dissolving in acids without gelatinizing. Cacoxene, to which it is allied, becomes dark reddish-brown before the blowpipe, and does not give the blue with cobalt nitrate.

Obs. Occurs at the slate quarries of York County, Pa., and also at Washington Mine, Davidson County, N. C.; at Magnet Cove, Ark. It was first discovered by Dr. Wavel, in clay slate in Devonshire. Occurs also in Bohemia and Bavaria.

Zepharovichite is near wavellite.

Mellite or *Honey stone.* In square octahedrons, looking like a honey-yellow resin; may be cut with a knife. It is an aluminum mellate. Found in Thuringia, Bohemia, Moravia, etc.

Dawsonite. Hydrous aluminum-calcium carbonate, from a felsyte dike near Montreal.

CERIUM, YTTRIUM, ERBIUM, LANTHANUM, DIDYMIUM.

Known in nature in the condition of fluorides, tantalates, columbates, phosphates, or carbonates, and also as constituents in several silicates.

Yttrocerite.

Massive, of a violet-blue color, somewhat resembling a purple fluor-spar; sometimes reddish-brown. Opaque. Lustre glistening. H.=4–5. G.=3·4–3·5.

Composition. Fluorine 25·1, lime 47·6, cerium protoxide 18·2, and yttria 9·1. Infusible alone before the blowpipe.

Obs. From Finbo and Broddbo, near Fahlun, in Sweden, with albite and topaz in quartz. Also from Mt. Mica, Maine; Massachusetts, probably in Worcester County; and from Amity, Orange County, N.Y.

Fluocerite **and** ***Fluocerine*** **are other fluorides containing cerium, from Sweden.**

Samarskite.

Trimetric. $I \wedge I = 122° 46'$. Usually massive, without cleavage, with a velvet-black color and shining submetallic lustre. Streak dark-reddish brown. Opaque. H.=5·5–6. G.=5·6–5·8.

Composition. Analyses of the American afford columbic and tantalic pentoxide, with sesquioxides of yttrium (12–15 per cent.), cerium, iron, and oxide of uranium. In the closed tube decrepitates and glows. B.B. fuses on the edges to a black glass. With salt of phosphorus in both flames, an emerald-green bead.

Obs. Occurs at Miask, in the Ural; also in masses, sometimes weighing many pounds, at the Mica mines of Western North Carolina, along with columbite.

Nohlite **is near samarskite, but contains 4·62 of water.**

Fergusonite. **A hydrous columbate of yttrium, erbium, cerium. Color brownish black; lustre dull, but brilliantly vitreous on a surface of fracture. B.B. infusible, but loses its color. From Sweden, Cape Farewell, Greenland, and Rockport, Mass.**

Kochelite **is near fergusonite.**

Yttro-tantalite. **A tantalate and columbate of yttrium, erbium, and iron. The different varieties are the black, the yellow, and brown or dark-colored. They are infusible. From Ytterby, Sweden, and at Broddbo and Finbo, near Fahlun.**

Euxenite. **A columbate and tantalate of yttrium, uranium, erbium, and cerium. Massive. Color brownish black. Streak reddish brown. B.B. infusible. From Norway; also from N. Carolina.**

Sipylite. **A columbate and tantalate of erbium and yttrium, resembling fergusonite in aspect. From Amherst County, Va.**

Pyrochlore, Microlite, Disanalyte, **under CALCIUM, p. 214.**

Æschynite. **In crystals, black to brownish yellow; lustre resinous to submetallic; streak gray to yellowish brown or black. H.=5–6. G.=4·9-5·1. A columbate and titanate of cerium, thorium, and lanthanum. From Miask, in the Urals, in feldspar with mica and zircon.**

Polymignite **and** ***Polycrase.*** **Related to æschynite.**

Rogersite. A hydrous columbate of yttria, in whitish crusts, on samarskite. From N. Carolina.

Monazite.

Monoclinic. In modified oblique rhombic prisms; $I \wedge I = 93° 10'$. Perfect and brilliant basal cleavage. Observed only in small imbedded crystals.

Color brown, brownish red; subtransparent to nearly opaque. Lustre vitreous inclining to resinous. Brittle. H.=5. G.=4·8–5·1.

Composition. A phosphate containing cerium, lanthanum, yttrium, didymium and thorium, with also a little tin, manganese, and lime. B.B. it colors the flame green when moistened with sulphuric acid and heated. Difficultly soluble in acids.

Diff. The brilliant easy transverse cleavage distinguishes monazite from sphene.

Obs. Occurs near Slatoust, Russia. In the United States it is found in small brown crystals, disseminated through a mica slate at Norwich, Conn.; also at Chester, Conn., and Yorktown, Westchester County, N. Y.

Cryptolite. A cerium phosphate in minute prisms (apparently six-sided), found with the apatite of Arendal, Norway. Color pale wine-yellow. G.=4·6.

Churchite. A phosphate of cerium, didymium and calcium; from Cornwall.

Xenotime. An yttrium phosphate having a yellowish-brown color, pale brown streak, opaque, and resinous in lustre. Crystals square prisms, with perfect lateral cleavage. H.=4–5. G.=4·6. Infusible alone before the blowpipe; insoluble in acids. From Lindesnaes, Norway; Ytterby, Sweden; gold washings of Clarkesville, Ga., and McDowell County, N. C.

Parisite. Is a carbonate containing cerium, lanthanum, and didymium, with fluorine. From New Granada.

Lanthanite. Occurs in thin minute tables or scales of whitish or yellowish color, and is a hydrous lanthanum carbonate. From Bastnäs, Sweden, and Saucon Valley in Lehigh County, Pa.

Tengerite. An yttrium carbonate. Found in thin coatings at Ytterby, Sweden.

Rhabdophane. A didymium and erbium phosphate; from Cornwall, with sphalerite (blende), which it resembles.

Rutherfordite. A blackish-brown vitreo-resinous mineral. From the gold mines of Rutherford County, N. C.

Allanite, Gadolinite, Keilhauite, and *Tscheffkinite,* are silicates containing either cerium or yttrium.

MAGNESIUM.

Magnesium occurs, in nature, as an oxide or hydrated oxide, and in the condition of sulphate, borate, nitrate, phosphate, carbonate and silicate.

The sulphates and nitrate of magnesia are soluble in water, and are distinguished by their bitter taste; the other native magnesian salts are insoluble. The presence of magnesia, when no metallic oxides are present, is indicated by a blowpipe experiment, explained on page 87.

Periclasite.—Periclase. Magnesium Oxide.

Isometric. In small grayish to dark-green imbedded crystals, with cubic cleavage. H. nearly 6. G.=3·674.

Composition. MgO (or the same as for *magnesia alba* of the shops), with a little iron. B.B. infusible. Soluble in acids without effervescence.

From Mount Somma, Vesuvius, Italy.

Brucite.—Magnesium Hydrate.

Rhombohedral. In foliated hexagonal prisms and plates; structure thin foliated, and thin laminæ easily separated and translucent; flexible but not elastic. Also fibrous. Lustre pearly. Color white, often grayish or greenish. H.=2·5. G.=2·35.

Composition. MgO_2H_2=Magnesia 69·0, water 31·0=100. B.B. infusible, but becomes opaque and alkaline. Soluble in hydrochloric acid without effervescence.

Diff. It resembles talc and gypsum, but is soluble in acids; it differs from heulandite and stilbite also by its infusibility.

Obs. Occurs in serpentine at Hoboken, N. J.; in Richmond County, N. Y.; in Dutchess County, N. Y., at Brewster's; at Texas, in Pennsylvania; also at Swinaness, in Unst, one of the Shetland Isles.

The fibrous variety has been called *nemalite;* it resembles amianthus; it occurs at Hoboken.

Hydromagnesite. A pearly crystalline, or earthy, white, hydrous carbonate of magnesia, from Hoboken, N. J., Texas, Pa., and elsewhere.

Spinel contains oxygen and magnesium along with aluminum. See page 195. Magnesium is also present in some magnetite, a variety of which is called *magnoferrite.*

Chlormagnesite. A magnesium chloride from Vesuvius.
Carnallite. A hydrous magnesium-potassium chloride.
Tachydrite. A hydrous magnesium-calcium chloride.

Epsomite.—Epsom Salt. Magnesium Sulphate.

Trimetric. $I \wedge I = 90° \ 34'$. Cleavage perfect parallel with the shorter diagonal. Usually in fibrous crusts, or botryoidal masses, of a white color. Lustre vitreous to earthy. Very soluble, and taste bitter and saline.

Composition. $Mg\,O_4\,S + 7aq$ = Sulphur trioxide 32·5, magnesia 16·3, water 51·2 = 100. Liquefies in its water of crystallization when heated. Gives much water which has an acid reaction, in the closed glass tube. B.B. on charcoal fuses, but finally gives an infusible mass that turns pink when moistened with cobalt nitrate and ignited.

Diff. The fine spicula-like crystalline grains of Epsom salt, as it appears in the shops, distinguish it from Glauber salt, which occurs usually in thick crystals.

Obs. The floors of the limestone caves of the West often contain Epsom salt in minute crystals mingled with the earth. In the Mammoth Cave, Ky., it adheres to the roof in loose masses like snowballs. It occurs as an efflorescence in the galleries of mines and elsewhere. The fine efflorescences suggested the old name *hair-salt.*

At Epsom, in Surrey, England, it occurs dissolved in mineral springs, and from this place the salt derived the name it bears. It occurs at Sedlitz, Aragon, and other places in Europe ; also in the Cordilleras of Chili ; and in a grotto in Southern Africa, where it forms a layer an inch and a half thick.

Its medical uses are well known. It is obtained for the arts from the bittern of sea-salt works, and quite largely from magnesian calcium carbonate, by decomposing it with sulphuric acid. The sulphuric acid takes the lime and magnesia, expelling the carbonic acid ; and the sulphate of magnesium remaining in solution is poured off from the calcium sulphate, which is insoluble. It is then crystallized by evaporation.

Polyhalite. A brick-red saline mineral, with a weak bitter taste, occurring in masses which have a somewhat fibrous appearance. A hydrous calcium-magnesium sulphate.

Kieserite. A hydrous magnesium sulphate ; from Stassfurt.

Picromeride. A hydrous potassium-magnesium sulphate; from Stassfurt.

Blœdite. A hydrous sodium-magnesium sulphate; **from the salt mines of Ischl, and near Mendoza.**

Lœweite. A hydrous sodium-magesium sulphate; **from Ischl. Contains more sulphur trioxide than Blœdite.**

Boracite.—Magnesium Borate.

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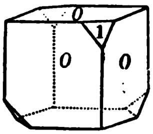

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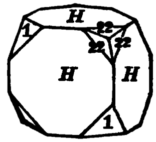

Isometric. Cleavage octahedral; but only in traces. Usual in cubes with only the alternate angles replaced; or having all replaced, but four of them different from the other four. The crystals are translucent and seldom more than a quarter of an inch through. Also massive. Color white or grayish; sometimes yellowish or greenish. Lustre vitreous. H.=7 when in crystals, but softer when massive. G.=2·97. Becomes electric when heated, the opposite angles of the cube becoming of opposite poles.

Composition. $Mg_3 O_{15} B_8 + \frac{1}{2}Mg Cl_2$=Boron trioxide 62·0, magnesia 31·0, chlorine 7·0=100. B.B. fuses easily with intumescence coloring the flame green. The fused globule becomes crystalline on cooling. Dissolves in hydrochloric acid, and moistened with cobalt nitrate turns pink on ignition.

Diff. Distinguished readily by its form, high hardness, and pyro-electric properties.

Obs. Boracite is found only with gypsum and common salt. It occurs near Luneberg in Lower Saxony, and near Kiel in the adjoining duchy of Holstein, also at Stassfürth, Prussia.

Rhodizite. **Resembles boracite in its crystals, but tinges the blowpipe flame deep red. It is supposed to be a lime-boracite. Occurs with the red tourmaline of Siberia.** ***Ludwigite.*** **A magnesium-iron borate; fibrous and dark green to black.**

Szaibelyite. **A hydrous magnesium borate, from Southeastern Hungary**

Warwickite. **In rhombic prisms of 93° to 94°, hair-brown to black with sometimes a copper-red tinge. A magnesium-titanium borate; from granular limestone of Edenville, N. Y.**

Sussexite. **A hydrous magnesium-manganese borate. Fibrous and pearly. G=3·42. from Mine Hill, Franklin Furnace, Sussex Co., N. J.**

Nitromagnesite. **Occurs in white deliquescent efflorescences, having a bitter taste, associated with calcium nitrate, in limestone caverns. It is used, like its associate, in the manufacture of saltpetre.**

Wagnerite. **A magnesium fluo-phosphate, occurring in yellowish or**

grayish oblique rhombic prisms. Insoluble. H.=5–5·5. G.=3·1. From Sälzburg, Austria. *Kjerulfine* is near wagnerite.

Hœrnisite and *Rœsslerite* are hydrous calcium arsenates.

Lüneburgite. A magnesium boro-phosphate, from Lüneburg.

Magnesite.—Magnesium Carbonate.

Rhombohedral. $R : R = 107° 29'$. Cleavage rhombohedral, perfect. Often massive, either granular, or compact and porcelain-like, in tuberose forms; also fibrous.

Color white, yellowish or grayish-white, or brown. Lustre vitreous; fibrous varieties often silky. Transparent to opaque. H.=3—4·5. G.=3.

Composition. MgO_3C=Carbon dioxide 52·4, magnesia 47·6=100. Infusible before the blowpipe. After ignition has an alkaline reaction. Nearly insoluble in cold dilute hydrochloric acid, but dissolves with effervescence in hot.

Diff. Resembles some varieties of calcite and dolomite; but from a concentrated solution no calcium sulphate is precipitated on adding sulphuric acid. The fibrous variety is distinguished from other fibrous minerals by its effervescence in hot acid, which shows it to be a carbonate.

Obs. Magnesite is usually associated with magnesian rocks, especially serpentine. At Hoboken, N. J., it occurs in this rock in fibrous seams; similarly at Lynnfield, Mass.; and in Canada, at Bolton, imperfectly fibrous, traversing white limestone.

When abundant it is a convenient material for the manufacture of magnesium sulphate or Epsom salt, to make which, requires simply treatment with sulphuric acid.

Hydromagnesite. A hydrous magnesium carbonate. Occurs with serpentine, at Hoboken, but more abundantly in Lancaster Co., Penn.

Dolomite. A magnesium and calcium carbonate. See page 219.

CALCIUM.

Calcium exists in nature in the state of fluorite, and this is its only binary compound. It occurs in ternaries in the state of sulphate, borate, columbate, phosphate, arsenate, carbonate, titanate and silicate. The carbonate (calcite and limestone) is one of the three most abundant of minerals. The fluoride and sulphate, and some silicates, are also of very common occurrence.

With the exception of the calcium nitrate, none of the native salts of lime are soluble in water except in small proportions. They give no odor, and no metallic reaction before the blowpipe; but they tinge the flame red, and many of them give up a part of their acid constituent, and become caustic and react alkaline. The *specific gravity* is below 3·2, and *hardness* not above 5.

Fluorite.—Fluor Spar. Calcium Fluoride.

Isometric. Cleavage octahedral, perfect. Commonly in crystals; rarely fibrous; often compact, coarse or fine granular. Figures 1 to 4 represent common forms.

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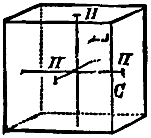

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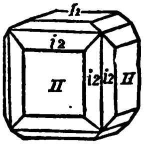

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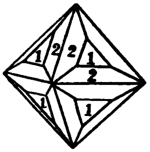

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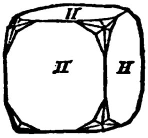

Colors usually bright; white, or some shade of light green, purple, or clear yellow are most common; rarely rose-red and sky-blue; colors of massive varieties often banded. Transparent, translucent or subtranslucent. H=4. G.=3–3·25. Brittle.

Composition. CaF_2=Fluorine 48·7, calcium 51·3=100. Phosphoresces when gently heated in the dark, affording light of different colors; in some varieties emerald-green; in others, purple, blue, rose-red, pink, or orange. B.B. decrepitates, and ultimately fuses to an enamel, which possesses an alkaline reaction; pulverized and moistened with sulphuric acid, hydrofluoric acid gas is given off which corrodes glass. The name *Chlorophane* has been given to the variety that affords a bright green phophorescence.

Diff. In its bright colors, fluorite resembles some of the gems, but its softness and its easy octahedral cleavage when crystallized at once distinguish it. Its strong phosphorescence is a striking characteristic; and also its affording easily, with sulphuric acid and heat, a gas that corrodes glass.

Obs. Fluorite occurs in gneiss, mica schist, clay slate, limestone, and sparingly in beds of coal either in veins or occupying cavities, or as imbedded masses. It is the gangue in some lead mines.

Cubic crystals of a greenish color, over a foot each way, have been obtained at Muscolonge Lake, St. Lawrence County, N. Y.; near Shawneetown on the Ohio, a beautiful purple fluor in grouped cubes of large size is obtained from limestone and the soil of the region; at Westmoreland, N. H., at the Notch in the White Mountains, Blue Hill Bay, Maine, Putney, Vt., and Lockport, N. Y., are other localities. The *chlorophane* variety is found with topaz at Trumbull, Conn.

In Derbyshire, England, fluor spar is abundant, and hence it has received the name of *Derbyshire spar.* It is a common mineral in the mining districts of Saxony.

Calcium fluoride also exists in the enamel of teeth, in bones and some other parts of animals; also in certain parts of many plants; and by vegetable or animal decomposition it is afforded to the soil, to rocks, and also to coal beds in which it has been detected.

Massive fluor receives a high polish, and is worked into vases, candlesticks and various ornaments, in Derbyshire, England. Some of the varieties from this locality, consisting of rich purple shades banded with yellowish white, are very beautiful. The mineral is difficult to work because brittle. Fluor spar is also used for obtaining hydrofluoric acid, which is employed in etching. To etch glass, a picture, or whatever design it is desired to etch, is traced in the thin coating of wax with which the glass is first covered; a very small quantity of the liquid hydrofluoric acid is then washed over it; on removing the wax, in a few minutes, the picture is found to be engraved on the glass. The same process is used for etching seals, and any siliceous stone will be attacked with equal facility. This application of fluor spar depends upon the strong affinity between fluorine and silicon. Fluor spar is also used as a flux to aid in reducing copper and other ores, and hence the name *fluor.*

Gypsum.—Hydrous Calcium Sulphate.

Monoclinic. $I \wedge I = 143° 42'$; $2i \wedge 2i + 111° 42'$. Figure 2 represents a common twin (or *arrow-head*) crystal. Cleavage parallel to $i\text{-}i$ very easy, affording thin pearly laminæ; parallel to O, imperfect, giving a vitreous surface; parallel to I, fibrous. Occurs also in laminated masses, often of large size; in fibrous masses, with a satin lustre; in stellated or radiating forms consisting of narrow laminæ; also granular and compact.

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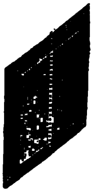

2.

When pure and crystallized it is as clear and pellucid as glass, and has a pearly lustre. Other varieties are gray, yellow, reddish, brownish, and even black, and opaque. H.= 1·5–2, or so soft as to be scratched by the finger-nail. G.=2·33. The plates bend in one direction and are brittle in another.

Composition. $Ca\,O_4\,S + 2\,aq$ = Sulphur trioxide 46·5, lime 32·6, water 20·9 = 100. B.B. becomes instantly white and opaque and exfoliates, and then fuses to a globule, which when placed upon moistened turmeric paper shows an alkaline reaction. In a closed tube much water is given off. Dissolves quietly in hydrochloric acid, and the solution gives a heavy precipitate with barium chloride.

The principal varieties are as follows:

Selenite, including the transparent crystallized gypsum, so called in allusion to its color and lustre from *selene*, the Greek word for *moon*.

Radiated and *Plumose gypsum*, having a radiated structure.

Fibrous gypsum or *satin spar*, white and delicately fibrous.

Snowy gypsum and *Alabaster*, including the white or light-colored compact gypsum having a very fine grain.

Diff. The foliated gypsum resembles some varieties of heulandite, stilbite, talc, and mica; and the fibrous looks like fibrous carbonate of lime, asbestus and some of the fibrous zeolites; but gypsum in all its varieties is readily distinguished by its softness; its becoming an opaque white powder immediately and without fusion before the blowpipe, and by not effervescing or gelatinizing with acids.

Obs. Gypsum forms extensive beds in certain limestones and clay beds, and also occurs in volcanic regions. New York, near Lockport, affords beautiful selenite and snowy gypsum in limestone. At Camillus and Manlius, N. Y., and in Davidson County, Tenn., are other localities. Fine crystals of the form represented in figure 5 come from Poland and Canfield, Ohio, and large groups of crystals from St. Mary's in Maryland. Troy, N. Y., also affords crystals in clay. In Mammoth Cave, Kentucky, alabaster occurs in imitation of flowers, leaves, shrubbery, and vines. Alabaster is obtained at Castelino in Italy, 35 miles from Leghorn. Massive gypsum occurs abundantly in New York, from Syracuse westward to the western extremity of Genesee County, accompanying the rocks which afford the brine springs; also in New Brunswick, especially at Hillsboro', where part is excellent alabaster; in Hants, Colchester, and other districts in Nova Scotia; also in Ohio, Illinois, Virginia, Tennessee, Arkansas, and Nova Scotia; and in connection with the Triassic beds of the Rocky Mountain region; also abundant in Nevada and California. It is abundant also in Europe.

Gypsum, when calcined, loses its water, becomes white, is easily ground to a powder. This powder, when mixed with a little water, takes up water again and becomes hard and compact. This gypsum is *plaster of Paris*, and is used for taking casts, making models, and for giving a *hard finish* to walls. *Alabaster* is cut into vases and various ornaments, statues, etc. It owes its beauty for this purpose to its snowy whiteness, translucency, and fine texture. Moreover, owing to its softness, it can be cut or carved with common cutting instruments. Gypsum is ground up and used for improving soils.

Anhydrite.—Anhydrous Calcium Sulphate.

Trimetric. In rectangular and rhombic prisms, cleaving easily in three directions, and readily breaking into square blocks. $I \wedge I = 100° 30'$; $1\breve{i} \wedge 1\breve{i} = 85°$ and 95°. Occurs also fibrous and lamellar, often contorted; also coarse and fine granular, and compact.

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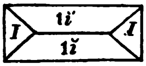

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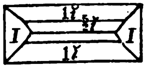
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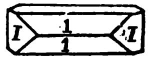


Color white, or tinged with gray, red, or blue. Lustre more or less pearly. Transparent to subtranslucent. H.=3–3·5. G.=2·9–3.

Composition. CaO_4S=Sulphur trioxide 58·8, lime 41·2=100. It is an *anhydrous* calcium sulphate. B.B. and with acids,

Gypsum - H_2O

its reactions are like those of gypsum, except that in the closed tube it gives no water.

A scaly massive variety containing a little silica has been named *Vulpinite;* contorted concretionary kinds are sometimes called *Tripestone.* Anhydrite is called by miners ***hard-plaster***, because harder than gypsum.

Diff. Its square forms of crystallization and cleavage are good distinguishing characters. Its three easy cleavages, at right angles with one another, look as if the crystallization were cubic; but there is some difference in the ease with which they may be obtained.

Obs. A fine blue crystallized anhydrite occurs with gypsum and calcareous spar in a black limestone at Lockport, and near Windsor in Nova Scotia, and Hillsboro' in New Brunswick. Foreign localities are at the salt mines of Bex in Switzerland, Hall in the Tyrol, Ischl in Upper Austria, Wieliczka in Poland, and elsewhere.

The vulpinite variety is sometimes cut and polished for ornamental purposes.

Bechilite. A hydrous calcium borate occurring as an incrustation at the Tuscan lagoons, Italy. A "hydrous borate of lime" reported by Hayes from Iquique, Peru, has been called *Hayesine;* but its composition has been questioned, it being referred to Ulexite. *Howlite.* A hydrous calcium borate, containing silica; Windsor, Nova Scotia. Called also *Silicoborocalcite.*

Ulexite or *Boronatrocalcite.* A hydrous calcium-sodium borate, in aggregations of fibres, from the dry plains of Iquique, Southern Peru; Nova Scotia, at Windsor, Brookville, and Newport; and Nevada, in Columbus mining district, and at Thiel Salt Marsh, in Esmeralda County.

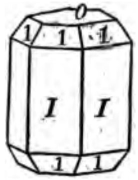
Cryptomorphite. Another hydrous calcium-sodium borate; Windsor, Nova Scotia. *Priceite* is a calcium borate of white color and chalky aspect, from Curry County, Oregon.

Hydroboracite. A hydrous calcium-magnesium borate, resembling gypsum in aspect.

Scheelite. Calcium tungstate, of pale yellowish-white color; H.= 4·5-5. G.=5·9-6·1. From Monroe, Conn.; North Carolina; Mammoth mining district, Nevada; Charity Mine, Idaho; Golden Queen Mine, Lake Co., Colorado; Seattle, Washington Territory; at Caldbeck Fell, near Keswick, England; in Bohemia, Hartz, Saxony, Hungary, Sweden, Vosges. *Cuproscheelite* has part of the calcium replaced by copper; from La Paz, Lower California.

Apatite.—Calcium Phosphate.

Hexagonal. In hexagonal prisms. The annexed figure represents a common form. Cleavage imperfect. Usually occurs in crystals; but occasionally massive; sometimes



mammillary with a compact fibrous structure. Small crystals are occasionally transparent and colorless, but the usual color is green, often yellowish green, bluish green, and grayish green; sometimes yellow, blue, reddish or brownish. Coarse crystals nearly opaque. Lustre vitreous to subresinous. H.=5. G. =3–3·25. Brittle. Some varieties phosphoresce when heated, and some become electric by friction.

Composition. $Ca_3 O_8 P_2 + \frac{1}{3} (Cl_2, F_2)$ = if without fluorine Phosphorus pentoxide 40·92, lime 53·80, chlorine 6·82=100. When chlorine is present in place of fluorine it is called *chlor-apatite*, and when the reverse, *fluor-apatite*. B.B. infusible except on the edges. Dissolves slowly in nitric acid without effervescence. Its constituents are contained in the bones and ligaments of animals, and the mineral has probably been derived in many cases from animal fossils.*

Massive apatite is often called *Phosphorite;* and the pale yellowish-green crystals, *Asparagus stone. Osteolite* is a white earthy apatite. *Eupyrchroite* is a fibrous mammillary variety from Crown Point, Essex County, N. Y.

Fossil excrements, called *coprolites,* occur in stratified rocks, and sometimes constitute extended beds; and they consist chiefly of calcium phosphate. *Guano* contains more or less calcium phosphate along with hydrous phosphates and some impurities.

Diff. Distinguished from beryl by its inferior hardness, it being easily scratched with a knife; from calcite by dissolving in acids without effervescence; from pyromorphite by its difficult fusibility, and giving no metallic reaction before the blowpipe. Phosphoric acid may be detected by moistening it with sulphuric acid and igniting it B.B., when it imparts a dirty green color to the flame.

Obs. Apatite occurs in gneiss, mica schist, hornblende schist, granular limestone. In microscopic crystals it is sparingly present in almost all crystalline rocks, the igneous as well as metamorphic. The best crystals in the United States occur in granular limestone; the crystals from the limestone of St. Lawrence County, N. Y., are

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* **Bones contain 25 per cent. of calcium phosphate, with some fluoride of calcium, 3 to 12 per cent. of calcium carbonate, some magnesium phosphate and sodium chloride, besides 33 per cent. of animal matter.**

among the largest yet discovered in any part of the world; one from Robinson's farm measured a foot in length and weighed 18 pounds; but they are nearly opaque and the edges are usually rounded. They occur with scapolite, sphene, etc. Edenville and Amity, Orange County, N. Y., afford fine crystals from half an inch to twelve inches long. At Westmoreland, N. H., fine crystals are obtained in a vein of feldspar and quartz; also at Blue Hill Bay in Maine. Bolton, Chesterfield, Chester, Mass., are other localities. A beautiful blue variety is obtained at Dixon's quarry, Wilmington, Delaware. Abundant in Burgess, Elmsley, Grand Calumet Id., Hull, Buckingham, Portland, etc., in Canada.

The name apatite, from the Greek *apatao, to deceive,* was given in allusion to the mistake of early mineralogists respecting the nature of some of its varieties.

Apatite, when abundant, is used like guano as a fertilizer, on account of its phosphoric acid. To make it capable of being taken up by plants it is treated first with a small portion of sulphuric acid, which renders the phosphoric acid soluble. When guano has been accumulated by birds, or other animals, over coral rock, a calcium carbonate (as on some coral islands), the waters in filtrating through it have often carried down the soluble phosphoric acid or phosphates into the underlying beds and turned them into calcium phosphate.

Brushite and *Metabrushite*. Hydrous calcium phosphates, found in guano.

Pyrophosphorite. A white earthy phosphate from a guano deposit, in the West Indies. Analysis gave it the composition of a pyrophosphate.

Pharmacolite and *Haidingerite* are hydrous calcium arsenates.

Nitrocalcite. Hydrous calcium nitrate. From caverns.

Pyrochlore. Occurs in small brown and brownish-yellow isometric octahedrons. A calcium-cerium columbate. G.=4·3–4·5. From Norway, Siberia.

Microlite. In crystals similar in form to those of pyrochlore, but in composition a calcium tantalate. G.=5·5–6. From Chesterfield, Mass., and Redding, Conn. *Hatchettolite* is a lime-uranium columbate, from North Carolina.

Disanalyte. In cubes in granular limestone, a columbate and titanate of calcium, cerium and iron. From the Kaiserstuhl.

Romeite and *Atopite* are calcium antimonates, the latter containing also iron and soda.

Calcite.—Calc Spar. Calcium Carbonate.

Rhombohedral. $R \wedge R$ (fig. 1) = 105° 5′. Cleavage easy, parallel with the faces of the fundamental rhombohedron.

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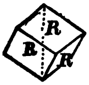

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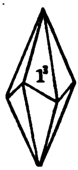

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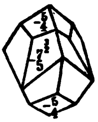

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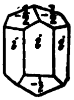


10.


Calcite with the form in fig. 7 is often called *dog-tooth spar*. Occurs fibrous with a silky lustre ; sometimes lamellar ; often coarse or fine granular, and compact.

The purest crystals are transparent with a vitreous lustre ; the impure massive varieties are often opaque, and without lustre, and even earthy. The colors of the crystals are either white or some light grayish, reddish or yellowish tint, rarely deep red ; occasionally topaz-yellow, rose or violet. The massive varieties are of various shades from white to black, generally dull unless polished. H.=3. G.=2·5–2·8.

Composition. $Ca\,O_3\,C$ = Carbon dioxide 44, lime 56=100. Sometimes impure from mixture with iron, silica, clay, bitumen, and other substances. B.B. infusible ; colors the flame reddish, gives up its carbon dioxide, is thereby made caustic, in which state it gives an alkaline reaction. Effervesces in dilute cold hydrochloric acid. Many varieties phosphoresce when heated.

The following are the principal varieties.

Iceland spar. Transparent crystalline calcite, first brought from Iceland. Shows well double refraction.

Satin spar. A finely fibrous variety with a satin lustre. Receives a handsome polish. Occurs usually in veins traversing rocks of different kinds.

Chalk. White and earthy, without lustre, and so soft as to leave a trace on a board. Forms mountain beds. Most chalk was made chiefly out of the shells of Rhizopods.

Rock milk. White and earthy like chalk, but still softer, and very fragile. It is deposited from waters containing lime in solution. *Rock meal* is a powdery variety.

Calcareous tufa. Formed by deposition from waters like rock milk, but more cellular or porous and not so soft.

Stalactite, Stalagmite. The name stalactite is explained on page 60. The deposits of the same origin that cover the floors of caverns are called stalagmite. They generally consist of differently colored layers, and appear banded or striped when broken. The so-called "Gibraltar rock" is stalagmite from a cavern in the rock of Gibraltar.

Limestone is a general name for all the massive varieties occurring in extensive beds.

Oölite, Pisolite. Oölite is a compact limestone, consisting of small round concretionary grains, looking like the spawn of a fish; the name is derived from the Greek *ōon, an egg.* Pisolite, a name derived from *pisum,* the Latin for *pea,* differs from oölite in being coarser; the spherules often have a concentric structure, and thus show their concretionary origin.

Argentine. A white shining limestone consisting of laminæ a little waving, and containing some silica.

Fontainebleau limestone. This name is applied to crystals of the form shown in figure 3, containing a large proportion of sand, and occurring in groups. They were formerly obtained at Fontainebleau, France, but the locality is exhausted.

Granular limestone. A limestone consisting of crystalline grains, and hence often called *crystalline* limestone. The coarser varieties when polished constitute the common *white and clouded marbles,* and are the material of which "marble" buildings are made. The finer are used for statuary, and are called *statuary marble.* The best is as clear and fine-grained as loaf sugar, which it much resembles.

Compact limestone. The limestones breaking with a smooth surface, without a distinctly granular texture, and dull in lustre unless polished. The rock is very variously colored. The colors are sometimes arranged in blotches, or veins. Kinds that are handsome when polished are used as marbles. A black color is common, and is usually due to carbonaceous material of organic origin, and is proved by the limestones becoming white when burnt.

Stinkstone, Anthraconite. A limestone which gives out a fetid odor when struck. This odor is caused by certain bituminous materials present in the rock.

Lithographic stone. A very compact fine-grained limestone of a gray or grayish-yellow color.

Hydraulic limestone. An impure limestone. It contains silica and alumina in such a condition that, when burned, it will make a cement that hardens under water.

Diff. Distinguished by being scratched easily with a knife, in connection with strongly effervescing in dilute acid, and its complete infusibility. Calcite is not so hard as aragonite, and possesses a very distinct cleavage, which aragonite does not.

Obs. Crystallized calc spar occurs in magnificent forms in the vicinity of Rossie, New York. One crystal from there, now in the Peabody Museum at New Haven, weighs 165 pounds. Some rose and purple varieties from this region are very beautiful. Large geodes of the dog-tooth spar variety occur in limestone at Lockport, along with gypsum and pearl spar. Leyden and Lowville, N. Y., are other localities. Bergen Hill, N. J., affords beautiful wine-yellow crystals in amygdaloidal cavities; also the Lake Superior copper mines. *Argentine* occurs near Williamsburg and Southampton, Mass. *Rock milk* covers the sides of a cave at Watertown, N. Y., and is now forming. *Stalactites* of great beauty occur in Weir's and other caves in Virginia and in the Western States; also in Ball's Cave at Scoharie, N. Y. *Chalk* occurs in England and Europe, and in Western Kansas in the United States. Granular limestones are common in the Eastern and Atlantic States, and compact limestones in the Middle and Western States, and some beds of the former afford excellent marble for building and some of good quality for statuary.

Any of the varieties of this mineral when burnt form *quicklime*, heat driving off the carbonic acid and leaving the lime in a caustic state. In this state it is used for making mortar by mixing with water and sand; a calcium hydrate results which becomes slowly carbonated through carbonic acid in the atmosphere. See further the chapter on Rocks, for the uses of limestone.

Aragonite.

Trimetric. In rhombic prisms; $I \wedge I = 116° 10'$. Cleavage parallel with I. Usually in compound crystals having the form of a hexagonal prism, with uneven or striated sides; or in stellated forms consisting of two or three flat crystals

Occurs also in globular and coralloidal shapes; also in fibrous seams in different rocks.

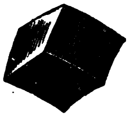
Color white or with light tinges of gray, yellow, green and violet. Lustre vitreous. Transparent to translucent. H.= 3·5–4. G.=2·931.

Composition. Same as for calcite, and its action before the blowpipe and with acids is the same, except that it falls to powder readily when heated. Some varieties contain a few per cent. of strontium carbonate, but this is not an essential ingredient. Distinguished from calcite by the absence of the cleavage of the latter, as well as the crystalline form; also by its higher specific gravity.

Obs. Aragonite occurs mostly in gypsum beds and in connection with iron ores; also in basalt and other rocks. The coralloidal forms are found in iron ore beds, and are called *Flos ferri, flowers of iron.* They look like a loosely intertwined or tangled white cord.

The *flos-ferri* variety occurs at Lockport with gypsum; also at Edenville, at the Parish iron ore bed in Rossie, and in Chester County, Pennsylvania. Aragon in Spain affords six-sided prisms of aragonite, associated with gypsum. This locality gave the name to the species. Also found at Bilin, in Bohemia, Tarnowitz in Silesia, and other places.

Dolomite.—Calcium-Magnesium Carbonate. Magnesian Carbonate of Lime.



Rhombohedral. $R \wedge R = 106° 15'$. Cleavage perfect parallel to *R*. Faces of rhombohedrons sometimes curved, as in the annexed figure. Often granular and massive, constituting extensive beds.

Color white or tinged with yellow, red, green, brown, and sometimes black. Lustre vitreous or pearly. Nearly transparent to translucent. Brittle. H.$=3·5$–4. G.$=2·8$–$2·9$.

Composition. $\frac{1}{2}Ca\frac{1}{2}Mg\,O_3\,C$ = Calcium carbonate 54·35, magnesium carbonate 45·65=100. Some iron or manganese is often present, replacing part of the magnesium or calcium. Dolomite resembles calcite, but differs in that unless finely pulverized it effervesces very sparingly, if at all, in cold dilute hydrochloric acid.

The princpal varieties of this species are as follows:

Dolomite. White, crystalline granular, often not distinguishable in external characters from granular limestone.

Pearl spar. In pearly rhombohedrons with curved faces.

Rhomb spar, Brown spar. In rhombohedrons, which become brown on exposure, owing to their containing 5 to 10 per cent. of oxide of iron or manganese.

A cobaltiferous variety has a red tint. A white compact siliceous variety has been called *Gurhofite.* Some hydraulic limestones are dolomite.

Diff. Distinctive characters nearly the same as for calcite. It is harder than that species, and differs in the angles of its crystals, and effervesces much less freely; but chemical analysis is often required to distinguish them.

Obs. Massive dolomite is common in Western New England and Southeastern New York, and constitutes much of the marble used for building. Crystallized specimens are obtained at the Quarantine, Richmond County, N. Y. Rhomb spar occurs in talc, at Smithfield, R. I.; Marlboro', Vt.; Middlefield, Mass.; pearl spar in crystals of the above form at Lockport, Niagara Falls, Rochester, Glen's Falls; gurhofite on Hustis's farm, Phillipstown, N. Y.

Dolomite was named in honor of the geologist and traveler, Dolomieu.

Dolomite burns to quicklime like calcite, and affords a more durable cement. The white massive variety is used extensively as marble. The magnesian lime has been supposed to injure soils; but this is believed not to be the case if it is air-slaked before being used. It is also employed in the manufacture of Epsom salts or magnesium sulphate.

Ankerite. Resembles brown spar, and, like that, becomes brown on exposure. Fundamental from a rhombohedron of 106° 12′. It is a calcium-magnesium-iron-and-manganese carbonate. The Styrian iron ore beds of Saltzburg are some of its foreign localities. It occurs in Nova Scotia, and in quartz veins in Western New Hampshire; Quebec, Canada, etc.

Hydrodolomite. A calcium-magnesium carbonate containing water. *Pennite* from Texas, Pa., is similar.

BARIUM AND STRONTIUM.

Barium and strontium occur in nature only in anhydrous ternary compounds of the following kinds: sulphate, carbonate, silicate; and in silicates only in combination with other basic elements. The species are characterized by high specific gravity, ranging from 3·5 to 4·8. Strontium gives a red color to the blowpipe flame; and barium, if strontium and other basic elements are absent, a characteristic green color.

Barite.—Heavy Spar. Barium Sulphate.

Trimetric. In modified rhombic and rectangular prisms, $I \wedge I=101^\circ 40'$; $O \wedge \frac{1}{2}\breve{i}=141^\circ 08'$; $O \wedge 1\breve{i}=127^\circ 18'$. Crystals usually tabular. Massive varieties often coarse lamellar; also columnar, fibrous, granular and compact. Lustre vitreous; sometimes pearly. Color white and sometimes tinged yellow, red, brown, blue, or dark brown. Transparent or translucent. H.=2·5–3·5. G.=4·3–4·7.

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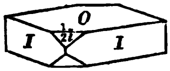

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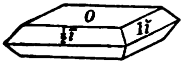

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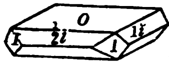

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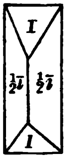

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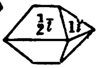

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Composition. BaO_4S, = Sulphur trioxide 34·3, baryta 65·7=100. Strontium and calcium are sometimes present replacing a little barium. B.B. fuses to a bead which reacts alkaline. Imparts a green color to the flame. After fusion with soda in the reducing flame on coal, and then placed on a silver coin and moistened, it produces a black stain, due to sulphur.

Barite is often present in mineral veins as the gangue of the ore. In this way it occurs at Cheshire, Conn.; Hatfield, Mass.; Rossie and Hammond, New York; Perkiomen, Pennsylvania, and the lead mines of the Mississippi Valley. Schoharie, and Pillar Point near Sackett's Harbor, are other localities; also near Fredericksburg and elsewhere, Virginia; Nova Scotia, etc. The variety from Pillar Point receives a fine polish and looks like marble, the colors being in bands or clouds.

Heavy spar is ground up and used to adulterate white lead. When white lead is mixed in equal parts with it, it is sometimes called *Venice white,* and another quality with twice its weight of barite is called *Hamburg white,* and another, one-third white lead, is called *Dutch white.* When the material is very white, a proportion of it gives greater opacity to the color, and protects the lead from being speedily blackened by sulphurous vapors; and these mixtures are therefore preferred for certain kinds of painting.

Dreelite is a barium-calcium sulphate.

Witherite.—Barium Carbonate.

Trimetric. $I \wedge I = 118° 30'$. Cleavage imperfect. Also in globular or botryoidal forms: often massive, and either fibrous or granular. The massive varieties have usually a yellowish or grayish-white color, with a lustre a little resinous, and are translucent. The crystals are often white and nearly transparent. H. =3–4. G.=4·29–4·35. Brittle.

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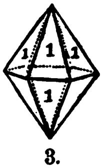

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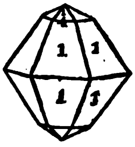

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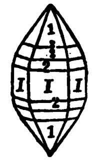

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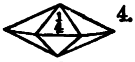

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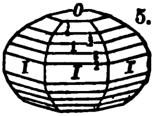


Composition. Ba O$_3$ C=Carbon dioxide 22·3, baryta 77·7=100. B. B. decrepitates and fuses easily, tingeing the flame green, to a translucent globule, which becomes opaque on cooling, and colors a moistened turmeric paper red. Effervesces in hydrochloric acid.

Diff. Distinguished by its specific gravity and fusibility from calcite and aragonite; its action with acids, from allied minerals that are not carbonates; by yielding no metal, from cerussite, and by tingeing the flame green, from strontianite.

Obs. The most important foreign localities of witherite are at Fallowfield in Northumberland (where it is mined). Alstonmoor in Cumberland, and Anglezark in Lancashire. It is also found in Silesia, Styria, and Sicily. In the United States it occurs at Lexington, Ky.

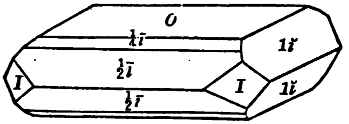
Witherite, from Fallowfield, is used in chemical works, in the manufacture of plate glass, and in France in the manufacture of beet sugar.

Barytocalcite. Occurs at Alstonmoor in Cumberland, England, in whitish monoclinic crystals. H.=4. G.=3·6–3·7. It is a barium-calcium carbonate.

Bromlite is a trimetric mineral, of the same composition, from Bromley Hill, near Alston, and from Northumberland, England.

Celestite.—Strontium Sulphate.

Trimetric. $I \wedge I = 103° 30'$ to $104° 30'$. Crystals rhombic prisms or tabular; often long and slender. Cleavage distinct parallel with *I*. Massive varieties: columnar or fibrous, forming layers half an inch or more thick with a pearly lustre; rarely granular. Color generally a tinge of blue, but sometimes clear white or reddish. Lustre vitreous or a little pearly; transparent to translucent. H.=3–3·5. G.=3·9–4. Very brittle.



Composition. SrO_4S=Sulphur trioxide 43·6, strontia 56·4=100. B.B. decrepitates and fuses, tinging the flame bright red to a milk-white alkaline globule, which gives an alkaline reaction. With soda on coal fuses to a mass which when moistened blackens silver.

Diff. From barite, which it resembles, it is distinguished by the bright red color it imparts to the blowpipe flame, and its less specific gravity; and from the carbonates, by not effervescing with acids.

Obs. Celestite is found in beds of sandstone or limestone, and also with gypsum, rock salt, and clay. A bluish celestine, in tabular and prismatic crystals, occurs at Strontian Island, Lake Erie; Scoharie, Lockport and Rossie, N.

Y., are other localities. A handsome fibrous variety occurs at Franktown, Huntingdon County, Pennsylvania. Sicily affords fine crystallizations associated with sulphur.

The pale *sky-blue* tint, so common with the mineral, gave origin to the name *celestite.*

Celestite is used in the arts for making the nitrate of strontia, which is employed for producing a red color in fireworks.

Strontianite.—Strontium Carbonate.

Trimetric. $I \wedge I = 117° 19'$. Cleavage parallel to *I*, nearly perfect. Occurs also fibrous and granular, and sometimes in globular shapes with a radiated structure within.

Color often a light tinge of green; also white, gray, and yellowish brown. Lustre vitreous, or somewhat resinous. Transparent to translucent. H.=3·5–4. G.=3·6–3·72. Brittle.

Composition. SrO_3C = Carbon dioxide 29·7, strontia 70·3=100. A small part of the strontium is often replaced by calcium. B.B. swells, throws out little sprouts, but does not fuse. Colors the flame bright red, and after heating possesses an alkaline reaction. Effervesces in cold dilute acid; sulphuric acid gives a precipitate of strontium sulphate.

Diff. Its effervescence with acids distinguishes it from minerals that are not carbonates; the color of the flame before the blowpipe, from witherite and all other carbonates; calcium salts also give a red color to the flame, but the shade is yellowish, and less brilliant.

Obs. Strontianite occurs in limestone at Scoharie, N. Y., in crystals, and also fibrous and massive; and in Jefferson County, N. Y., and Mifflin County, Penn. Strontian in Argyleshire, England, was the first locality known, and gave the name to the mineral and the metal strontium. It occurs there, with galenite, in stellated and fibrous groups and in crystals.

This mineral is used for preparing the strontium nitrate.

POTASSIUM AND SODIUM.

Potassium and sodium occur in nature in the state of chloride, sulphate, nitrate, and carbonate, and are constituents in many silicates.

Sylvite.—Potassium Chloride.

Isometric. White or colorless, with vitreous lustre, and taste nearly that of common salt. The crystals are often cubes with octahedral planes, like fig. 8 on p. 19. H.=2. G.=1·9–2.

Composition. K Cl=Chlorine 47·5, potassium 52·5=100. From Vesuvius, about the fumaroles of the volcano.

Halite.—Common Salt. Sodium Chloride.

Isometric. In cubes and other related forms. Sometimes crystals have the shape of a shallow four-sided cup, and are called hopper-shaped crystals; they were formed floating, the cup receiving its enlargement at the margin, this being the part which lay at the surface of the brine where evaporation was going on. Cleavage cubic, perfect.

Color usually white or grayish, sometimes rose-red, yellow, and of amethystine tints. Taste saline. H.=2. G.=2·257.

Composition. Na Cl=Chlorine 60·7, sodium 39·3=100. Crackles or decrepitates when heated; fuses easily, coloring the flame deep yellow.

Diff. Distinguished by its taste, solubility, and blowpipe characters.

Obs. Salt occurs in extensive but irregular beds, usually associated with gypsum, anhydrite, and clays or sandstone. It occurs in formations of all ages, from the Silurian to the present time. It exists in the Pyrenees, in the valley of Cardona and elsewhere, forming hills 300 to 400 feet high; in Poland and Wieliczka; at Hall in the Tyrol, and along a range through Reichenthal in Bavaria, Hallein in Saltzburg, Hallstadt, Ischl and Ebensee in Upper Austria, and Aussee in Styria; in Hungary at Marmoros and elsewhere; in Transylvania, Wallachia, Galicia and Upper Silesia; at Vic and Dieuze in France; at Bex in Switzerland; in Cheshire, England; in Northern Africa in vast quantities forming hills and extended plains; in Northern Persia at Tiflis; in India in the province of Lahore, and in the valley of Cashmere; in China and Asiatic Russia; in South America, in Peru and the Cordilleras of New Granada.

Among the most remarkable deposits are those of Poland and Hungary. The former, near Cracow, have been worked since the year 1251, and it is calculated that there is still enough salt remaining to supply the whole world for many centuries. Its deep subterranean regions are excavated into houses, chapels and other ornamental forms, the roof being supported by pillars of salt; and when illuminated by lamps and torches, they are objects of great splendor.

The salt is often impure with clay, and is purified by dissolving it in large chambers, drawing it off after it has settled, and evaporating it again. The salt of Norwich (in Cheshire) is in masses 5 to 8 feet in diameter, which are nearly pure, and it is prepared for use by crushing it between rollers.

In North America, beds of rock salt exist at Goderich in Canada; at Wyoming in Western New York (reached by boring to a depth of 1,279 feet); in Washington County, in Virginia; and extensively at Petite Anse in Louisiana, where it underlies 144 acres; in Nevada, at several localities; in the Salmon River Mountains, Oregon.

Brine springs also proceed from rocks of various ages; and often they are indications of deep-seated beds of rock salt.

The salt of Western New York, and Goderich, Canada, is of the Salina period of the Upper Silurian; the brine springs of Michigan, from shales and marlytes of the Subcarboniferous period; those of the salt beds of Norwich, England, in magnesian limestone of the Permian; those of the Vosges and of Saltzburg, Ischl, and the neighboring regions, in marly sandstone of the Triassic; those of Bex, in Switzerland, in the Lias formation; that of Wieliczka, Poland, and the Pyrenees, in the Cretaceous or chalk formation; that of Catalonia, in the Tertiary; that of Louisiana, in the Quaternary, and large deposits are still more recent; and besides there are lakes that are now evaporating and producing salt depositions.

Vast lakes of salt water exist in many parts of the world. The Great Salt Lake of Utah has an area of 2,000 square miles, and is remarkable for its extent, considering that it is situated toward the summit of the Rocky Mountains, at an elevation of 4,200 feet above the sea. Its waters contain 20 per cent. of sodium chloride (common salt). The dry regions of these mountains and of Southwestern California are noted for salt licks and lakes. In Northern Africa large lakes as well as hills of salt abound, and the deserts of this region and Arabia abound in saline efflorescences.

The Dead and Caspian Seas, and the lakes of Khoordistan, are salt. From 20–26 per cent. of the weight of the water from the Dead Sea are solid salts, of which 10 per cent. are common salt. Over the pampas of La Plata and Patagonia there are many ponds and lakes of salt water.

The greater part of the salt made in this country is obtained by evaporation from salt springs. Those of Salina and Syracuse are well known; and many nearly as valuable are worked in Ohio and other Western States. At the best New York springs a bushel of salt is obtained from every 40 gallons. But the discovery of rock salt at Wyoming, west of Syracuse, may lead to further discoveries, which will make the brines of New York of comparatively little value. To obtain the brine, wells from 50 to 150 feet deep are sunk by boring. It is then raised by machinery.

The process of evaporation under the heat of the sun is extensively employed in hot climates for making salt from sea water, which affords a bushel for every 300 or 350 gallons. For this purpose a number of large shallow basins are made adjoining the sea; they have a smooth bottom of clay, and all communicate with one another. The water is let in at high tide and then shut off for the evaporation to go on. This is the simplest mode, and is used even in uncivilized countries, as among the Pacific Islands.

Mirabilite.—Glauber Salt. Hydrous Sodium Sulphate.

Monoclinic. Occurs in efflorescent crusts of a white or yellowish-white color; also in many mineral waters. Taste cool, then feebly saline and bitter.

Composition. $Na_2O_4S + 10aq$ = Sulphur trioxide 24·8, soda 19·3, water 55·9=100.

Diff. It is distinguished from Epsom salt, for which it is sometimes mistaken, by its coarse crystals, and the yellow color it gives to the blowpipe flame.

It is made in enormous amounts from common salt, its production being one stage in the manufacture of sodium carbonate. It is used in medicine, and is known by the familiar name of "salts."

Obs. On Hawaii, one of the Sandwich Islands, in a cave at Kailua, Glauber salt is abundant, and is constantly forming. It is obtained by the natives and used as medicine. Glauber salt occurs in efflorescences on the limestone below

Genesee Falls, near Rochester, N.Y. It is also obtained in Austria, Hungary, and elsewhere in Europe.

The artificial salt was first discovered by a German chemist by the name of Glauber.

Aphthitalite (*Arcanite*). Potassium sulphate, K_2O_4S=Sulphate trioxide 45·9, potash 54·1=100. Found at Vesuvius. *Misenite* is a hydrous potassium sulphate from a cavern near Misene.

Thenardite. Sodium sulphate Na_2O_4S=Sulphur trioxide 43·7, soda 56·3=100. From Spain, Bolivia, Tarapaca, in Peru; Slate Range, San Bernardino Co., California; and in Nevada.

Glauberite. Sodium-calcium sulphate. In monoclinic crystals, at Villa Rubia, in New Castile, Aussee, in Austria, and other salt beds.

Polyhalite and *Picromeride* are hydrous magnesium-potassium sulphates; *Blœdite* and *Löweite* hydrous magnesium-sodium sulphates; *Syngenite*, a hydrous calcium-potassium sulphate.

Borax.—Hydrous Sodium Biborate. Tinkal.

Monoclinic. In oblique rhombic prisms $I \wedge I=87°$. Cleavage parallel with *i-i* perfect. The crystals are white and transparent, with a glassy lustre. H.=2–2·5. G.=1·716. Taste sweetish-alkaline.

Composition. $Na_2O_7B_4+10aq$=Boron trioxide 36·6, soda 16·2, water 47·2=100. B.B. swells up to many times its bulk and becomes opaque white, and finally fuses to a glassy globule.

Obs. Borax was originally brought from a salt lake in Thibet, where it is dug in considerable masses from the edges and shallow parts of the lakes. The holes thus made in a short time become filled again with borax. The crude borax was formerly sent to Europe under the name of *tinkal*, and there purified for the arts. It has also been found in Peru and Ceylon. It has been extensively made from the boracic acid of the Tuscan lagoons by the reaction of this acid on sodium carbonate.

Borax occurs under like circumstances in California and Nevada, or is manufactured from other borates in solution or in the solid state. Localities in California are Borax Lake and its vicinity, north of San Francisco; also near Walker's Pass, Sierra Nevada; at Mono and Owens Lakes, and at Death Valley, near the borders of Nevada; in the Slate Range, in San Bernardino County; and in Nevada, at Little Salt Lake, near Ragtown, on the Pacific Railroad, and at Columbus Marsh. The Columbus Marsh, in Nevada, near lat. 38° 5′ N. and long. 118° W., 46 miles north of trail from Mono Lake, is a deposit, 10 miles long by 7 wide, of borates and other salts, chiefly borax, calcium borate, sodium sulphate, and common salt. The large deposits of "priceite" in Southern Oregon, and of ulexite, in the "Cane Spring District," 20 miles west of San Bernardino, and at the Columbus Marsh, are other sources of borax. The amount of borax received at San Francisco during the year 1876 was 5,180,910 pounds, and in 1877, 4,154,209 pounds.

Nitre.—Potassium Nitrate.

Trimetric. In modified right rhombic prisms; $I:I=118° 50'$. Usually in thin white subtransparent crusts, and in needleform crystals on old walls and in caverns. Taste saline and cooling. $H=2$. $G=1·97$.

Composition. K_2O_2N=Nitrogen pentoxide (N_2O_5) 53·4, potash 46·6. Burns vividly on a live coal.

Diff. Distinguished readily by its taste and its vivid action on a live coal; and from sodium nitrate, which it most resembles, by its not becoming liquid on exposure to the air.

Nitre, called also saltpetre, is employed in making gunpowder, forming 75 to 78 per cent. in shooting powder, and 62 in mining powder. The other materials are sulphur (10 per cent., for shooting powder to 20 for mining) and charcoal (12 to 14 for shooting powder and 18 for mining). It is also extensively used in the manufacture of nitric and sulphuric acids; also for pyrotechnic purposes, fulminating powders, and sparingly in medicine.

Obs. Occurs in many of the caverns of Kentucky and other Western States, scattered through the earth that forms the floor of the cave. In procuring it, the earth is lixiviated, and the lye, when evaporated, yields the nitre. India is its most abundant locality, where it is obtained largely for exportation.

Spain and Egypt also afford large quantities of nitre for commerce. This salt forms on the ground in the hot weather succeeding copious rains, and appears in silky tufts or efflorescences; these are brushed up by a kind of broom, lixiviated, and after settling, evaporated and crystallized. In France, Germany, Sweden, Hungary, and other countries, there are artificial arrangements called *nitriaries* or nitre beds, from which nitre is obtained by the decomposition mostly of the nitrates of lime and magnesia which form in these beds. Refuse animal and vegetable matter putrefied in contact with calcareous soils produces nitrate of lime, which affords the nitre by reaction with carbonate of potash. Old plaster lixiviated affords about 5 per cent. This last method is much used in France. The nitric acid of the cavern nitrates comes from the atmosphere, which also consists of nitrogen and oxygen ; but the combination takes place through the agency of a peculiar kind of microscopic plant.

Nitratine.—Soda Nitre. Sodium Nitrate. Cubic Nitre.

Rhombohedral ; $R:R=106° 33'$. Also in crusts or efflorescences, of white, grayish and brownish colors. Taste cooling. Soluble and very deliquescent.

Composition. Na_2O_3N=Nitrogen pentoxide 63·5, soda 36·5=100. Burns vividly on coal, with a yellow light.

Diff. It resembles nitre (saltpetre), but deliquesces, and gives a deep yellow light when burning.

Obs. In the district of Tarapaca, Northern Chili, the dry Pampa for an extent of forty leagues is covered with beds of this salt, mixed with gypsum, common salt, glauber salt, and remains of recent shells.

It is used extensively in the manufacture of nitric acid. It is also used in making nitre by replacing the sodium by potassium. In 1866, one million quintals of this salt were exported from Chili.

Natron.—Hydrous Sodium Carbonate. Carbonate of Soda.

Monoclinic. Generally in white efflorescent crusts, sometimes yellowish or grayish. Taste alkaline. Effloresces on exposure, and the surface becomes white and pulverulent.

Composition. $Na_2O_3C+10aq$=Carbon dioxide 26·7, soda 18·8, water 54·5=100. Effervesces strongly with acids.

Diff. Distinguished from other soda salts by effervescing, and from trona, by efflorescing on exposure.

Obs. This salt is found in solution in certain waters, from which it is crystallized in efflorescences by evaporation. Abundant in the soda lakes of Egypt ; also in lakes at Debreczin, in Hungary ; in Mexico, north of Zacatecas, and elsewhere. Sparingly dissolved in the Seltzer and Carlsbad waters.

This salt (but the artificially prepared) is extensively used in the manufacture of soap and glass, and for many other purposes.

Trona. A hydrous sodium sesquicarbonate occurs in the province of Suckenna, in Africa, between Tripoli and Fezzan, where it forms a fibrous layer an inch thick beneath the soil. It is abundant at a lake in Maracaibo, 48 miles from Mendoza; and forms an extensive bed in Churchill County, Nevada.

Thermonatrite. A hydrous sodium carbonate of the formula Na_2O_3C+aq. An anhydrous sodium carbonate is stated to exist native.

Gay-Lussite. Occurs in white brittle monoclinic crystals. Composition $\frac{1}{2}Na\frac{1}{2}Ca\,O_3\,C+2\frac{1}{2}aq$. From Lagunilla, in Maracaibo, and Little Salt Lake, near Ragtown, in Nevada.

AMMONIUM.

The salts of ammonia are more or less soluble in water, and are entirely and easily volatilized before the blowpipe. When treated with caustic lime or potassa, ammonia is liberated, and is recognized by its odor and the reaction of the vapors on test papers.

Salmiak.—Sal Ammoniac, Ammonium Chloride.

Occurs in white crusts or efflorescences, often yellowish or gray. Crystallizes in regular octahedrons. Translucent—opaque. Taste saline and pungent. Soluble in three parts of water.

Composition. NH_4Cl=Chlorine 66·3, ammonium 33·7=100. Gives off the odor of *ammonia* when powdered and mixed with quicklime.

Obs. Occurs in many volcanic regions, as at Etna, Vesuvius, and the Sandwich Islands, where it is a product of volcanic action. Occasionally found about ignited coal seams.

The sal ammoniac of commerce is manufactured from animal matter or coal soot. It is generally formed in chimneys of both wood and coal fires. In Egypt, whence the greater part of this salt was formerly obtained, the fires of the peasantry are made of the dung of camels; and the soot which contains a considerable portion of the ammoniacal salt is preserved and carried in bags to the works, where it is obtained by sublimation. Bones and other animal matters are used in France. A liquid condensed in the gas works, is also used in its production.

It is a valuable article in medicine, and is employed by tinmen in soldering to prevent the oxidation of copper surfaces; also in a variety of metallurgical operations.

Mascagnite. A hydrous ammonium sulphate. In mealy crusts, of a yellowish-gray or lemon-yellow color; translucent; taste pungent and bitter. *Composition* $(NH_4)_2O_4S+H_2O$=Sulphur trioxide 53·3, ammonia 22·8, water 23·9. Easily soluble in water. Occurs at Etna, Vesuvius, and the Lipari Islands. It is one of the products from the combustion of anthracite coal.

Lecontite is hydrous ammonium-sodium sulphate. *Boussingaultite* is a hydrous ammonium-magnesium sulphate, from Tuscany.

Struvite. A hydrous ammonium-magnesium phosphate; occurring in yellowish crystals, slightly soluble in water; found on the site of an old church in Hamburg, where there had been quantities of cattle dung.

Tschermigite. An ammonia alum from Tschermig, Bohemia, and Utah County, Utah

Larderellite. A white tasteless ammonium borate, from the Tuscan lagoons.

Hydrous ammonium phosphate and *Ammonium bicarbonate* (*Teschemacherite*) have been detected in guano; also, Hydrous sodium-ammonium phosphate, called *Stercorite.*

HYDROGEN.

Hydrogen is the basic constituent in hydrochloric acid, and in water.

Hydrochloric Acid.—Muriatic Acid.

A gas, consisting of Chlorine 97·26, hydrogen 2·74=100 $=HCl$. It has a pungent odor, and is acrid to the skin.

It is rapidly dissolved by water. If passed into a solution of nitrate of silver, it produces a white precipitate which soon blackens on exposure. It is given out whenever common salt is acted on by sulphuric acid, and occasionally by volcanoes.

WATER.

Water (hydrogen oxide) is the well-known liquid of streams and wells. The purest natural water is obtained by melting snow, or receiving rain in a clean glass vessel; but it is absolutely pure only when procured by distillation. It consists of hydrogen 1 part by weight, and oxygen 8 parts, or hydrogen 11·11, oxygen 88·89=100. It becomes solid at 32° Fahrenheit (or 0° Centigrade), and then crystallizes, and constitutes ice or snow. The crystals are of the hexagonal system. Flakes of snow consist of a congeries of minute crystals, and stars, like the figures on page 4, may often be detected with a glass. Various other allied forms are also assumed. The rays meet at an angle of 60°, and the branchlets pass off at the same angle with perfect regularity. The density of water is greatest at 39° 2′ F.; below this it expands as it approaches 32°, owing to incipient crystallization, and in the state of ice it is only 0·920. It boils at 212° F. A cubic inch of pure water at 62° F. and 30 inches of the barometer, weighs 252·458 grains, which equals 16·386 grams; and a cubic foot of water weighs 62·355 pounds avoirdupois. A pint, United States standard measure, holds just 7,342 troy grains of water, which is little above a pound avoirdupois (7,000 grains troy).

Water, as it occurs on the earth, contains some atmospheric air, without which the best would be unpalatable. This air, with some free oxygen also present, is necessary to the life of aquatic animals. In most spring water there is a minute proportion of salts of calcium (sulphate, chloride or carbonate), often with a trace of common salt, carbonate of magnesium and some alumina, iron, silica, phosphoric acid, carbonic acid, and certain vegetable acids. These impurities constitute usually from $\frac{1}{10}$ to 10 parts, in 10,000 parts by weight. The water of Long Pond, near Boston, contains about ½ a part in 10,000; the Schuylkill of Philadelphia, about 1 part in 10,000; the Croton, used in New York city, 1 to 1½ parts in 10,000. Nitric acid is usually found in rain water combined with ammonia; river waters are ordinarily the purest of natural waters, unless they have flowed through a densely populated region.

Sea water contains from 32 to 37 parts of solid substances in solution in 1,000 parts of water. The largest amount in the Atlantic, 36·6 parts, is found under the equator, away from the land or the vicinity of fresh-water streams; and the smallest in narrow straits, as Dover Straits, where there are only 32·5 parts. In the Baltic and Black Seas, the proportion is only one-third that in the open ocean. Of the whole, one-half to two-thirds is common salt (sodium chloride). The other ingredients are magnesium salts (chloride and sulphate), amounting to four-fifths of the remainder, with sulphate and carbonate of calcium, and traces of bromides, iodides, phosphates, borates and fluorides. The water of the British Channel affords water 964·7 parts in 1,000, sodium chloride 27·1, potassium chloride 0·8, magnesium chloride 3·7, magnesium sulphate 2·30, calcium sulphate 1·4, calcium carbonate 0·03, with some magnesium bromide and probably traces of iodides, fluorides, phosphates and borates. The bitter taste of sea water is owing to the salts of magnesium present.

The waters of the Dead Sea contain 200 to 260 parts of solid matter in 1,000 parts (or 20 to 26 per cent.), including 7 to 10 per cent. of common salt, the same proportion of magnesian salts, principally the chloride, 2½ to 3½ per cent. of calcium carbonate and sulphate, besides some bromides and alumina. The density of these waters is owing to this large proportion of saline ingredients. The brine springs of New York and other States south and west, are well-known sources of salt (see under Common salt). Many of the springs afford bromine, and large quantities of it are manufactured for making photographic plates and for other purposes.

Mineral waters vary much in constitution. They often contain iron in the state of bicarbonate, like those of Saratoga and Ballstown, and are then called *chalybeate* waters, from the ancient name for iron or steel, *chalybs*, derived from the name of a country on the Baltic. Hydrogen sulphide is often held in mineral waters and imparts to them its odor and taste; such are the so-called *sulphur springs*.

Minute traces of salts of zinc, arsenic, lead, copper, antimony and tin, have been found in some waters. Whatever is soluble in a region through which waters flow, will of course be taken up by them, and many ingredients are soluble in minute proportions, which are usually described as insoluble.

III. SILICA AND SILICATES.

I. SILICA.

Quartz.

Rhombohedral. Occurs usually in six-sided prisms, more or less modified, terminated with six-sided pyramids : $R \wedge R = 94° 15'$. No cleavage apparent, seldom even in traces; but sometimes obtained by heating the crystal and plunging it into cold water. Sometimes in coarse radiated forms;

also coarse and fine granular; also compact, either amorphous, or presenting stalactitic and mammillary shapes.

Crystals often as pellucid as glass, and colorless; sometimes topaz-yellow, amethystine, rose, smoky, or other tints. Also of all degrees of transparency to opaque, and of various shades of yellow, red, green, blue and brown colors to black. In some varieties the colors are in bands, stripes, or clouds. H.=7. G.=2·5–2·8.

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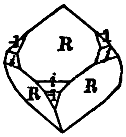

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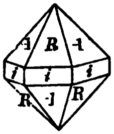

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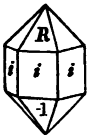

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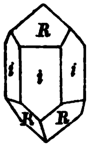

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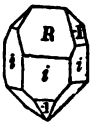

Composition. SiO_2=Oxygen 53·33, silicon 46·67=100. Opaque varieties often contain oxide of iron, clay, chlorite, or some other mineral disseminated through them. B.B. infusible. With soda, fuses with effervescence.

Diff. Quartz is exceedingly various in color and form, but may be distinguished, by (1) absence of true cleavage; (2) its hardness; (3) its infusibility before the blowpipe; (4) its insolubility with either of the common acids; (5) its effervescence when heated B.B. with soda; and (6) when crystallized, by the forms of its crystals, which are almost always six-sided prisms terminating in six-sided pyramids.

The varieties of quartz owe their peculiarities either to crystallization, mode of formation, or impurities, and they fall naturally into three series.

I. The *vitreous varieties,* distinguished by their glassy fracture.

II. The *chalcedonic varieties,* having a subvitreous or a waxy lustre, and generally translucent.

III. The *jaspery cryptocrystalline varieties,* having barely a glimmering lustre or none, and opaque.

I. VITREOUS VARIETIES.

Rock Crystal. Pure pellucid quartz.

This is the mineral to which the word *crystal* was first applied by the ancients; it is derived from the Greek *krustallos,* meaning *ice.* The pure specimens are often cut and used in jewelry, under the name of "white stone."

It is often used for optical instruments and spectacle glasses, and even in ancient times was made into cups and vases. Nero is said to have dashed to pieces two cups of this kind on hearing of the revolt that caused his ruin, one of which cost him a sum equal to $3,000.

Amethyst. Purple or bluish-violet, and often of great beauty. The color is owing to a trace of manganese oxide. It was called amethyst on account of its supposed preservative powers against intoxication. When finely and uniformly colored, highly esteemed as a gem.

Rose Quartz. Pink or rose-colored. Seldom occurs in crystals, but generally in masses much fractured, and imperfectly transparent. The color fades on exposure to the light, and on this account it is little used as an ornamental stone, yet is sometimes cut into cups and vases.

False Topaz. Light yellow pellucid crystals. They are often cut and set for topaz. The absence of cleavage distinguishes it from true topaz. The name *citrine,* often applied to this variety, alludes to its yellow color.

Smoky Quartz. Crystals of a smoky tint; the color is sometimes so dark as to be nearly black and opaque except in splinters. It is the *cairngorm* stone.

Milky Quartz. Milk-white, nearly opaque, massive, and of common occurrence. It has often a greasy lustre, and is then called *greasy quartz.*

Prase. Leek-green, massive; resembling some shades of beryl in tint, but easily distinguished by the absence of cleavage and its infusibility. Supposed to be colored by a trace of iron silicate.

Aventurine Quartz. Common quartz spangled throughout with scales of golden-yellow mica. It is usually translucent, and gray, brown, or reddish brown in color.

Ferruginous Quartz. Opaque, and either of yellow, brownish-yellow, or red color. The color is due to the presence of iron oxide as an impurity, the red to the anhydrous oxide, and the brownish yellow to the hydrous oxide.

II. CHALCEDONIC VARIETIES.

Chalcedony. Translucent, massive, with a glistening and somewhat waxy lustre; usually of a pale grayish, bluish, or light brownish shade. Often occurs lining or filling cavities in amygdaloidal rocks, and sometimes in other kinds. These cavities are nothing but little caverns, into which siliceous waters have filtrated at some period. The stalactites are "icicles" of chalcedony, hung from the roof of the cavity. Some of these chalcedony grottos are several feet in diameter. Large geodes of this kind occur in the Keokuk limestone in Illinois and Iowa.

Chrysoprase. Apple-green chalcedony. It is colored by nickel.

Carnelian. A bright red chalcedony, generally of a clear rich tint. It is cut and polished and much used in the more common jewelry. It is often cut for seals and beads.

Sard. A deep brownish-red chalcedony, of a blood-red color by transmitted light.

Agate. A variegated chalcedony. The colors are distributed in clouds, spots, or concentric lines. These lines take straight, circular, or zigzag forms; and when the last it is called *fortification agate,* so named from the resemblance to the angular outlines of a fortification. These lines are the edges of layers of chalcedony, and these layers are the successive deposits during the process of its formation. *Mocha stone* or *Moss agate* is a brownish agate, consisting of chalcedony with dendritic or moss-like delineations, of an opaque yellowish-brown color. They arise from disseminated iron oxide. All the varieties of agate are beautiful stones when polished, but are not much used in fine jewelry. The colors may be darkened by boiling the stone in oil, and then dropping it into sulphuric acid; a little oil is absorbed by some of the layers, which becomes blackened or charred by the acid.

Onyx. A kind of agate having the colors arranged in flat horizontal layers; the colors are usually light clear brown and an opaque white. When the stone consists of sard and white chalcedony in alternate layers, it is called *sardonyx.* Onyx is the material used for cameos, and is well fitted for this kind of miniature sculpture. The figure is carved out of one layer and stands in relief on another. A noted ancient cameo is the Mantuan vase at Brunswick. It was cut from a single stone, and has the form of a cream-pot, about 7 inches high and 2½ broad. On its outside, which is of a brown color, there are white and yellow groups of raised figures, representing Ceres and Triptolemus in search of Proserpine.

Cat's Eye is greenish-gray translucent chalcedony, having a peculiar opalescence, or glaring internal reflections, like the eye of a cat, when cut with a spheroidal surface.

The effect is owing to filaments of asbestus. It comes from Ceylon and Malabar, ready cut and polished, and is a gem of considerable value.

Flint, Hornstone. Massive compact silica, of dark shades of smoky gray, brown, or even black, and feebly translucent, it breaking with sharp cutting edges and a conchoidal surface. Flint occurs in nodules of chalk: not unfrequently the nodules are in part chalcedonic. Hornstone differs from flint in being more brittle ; it is often found in limestone.

Chert is an impure hornstone. Limestones containing hornstone or chert are often called *cherty* limestone.

Plasma. A faintly translucent variety of chalcedony approaching jasper, of a green color, sprinkled with yellow and whitish dots.

III. JASPERY VARIETIES.

Jasper. A dull red or yellow siliceous rock, containing some clay and yellow or red iron oxide, the red, the anhydrous oxide, and the yellow, the hydrous oxide. Heat drives off the water from the yellow jasper and turns it red. It also occurs of green and other shades. *Riband jasper* is a jasper consisting of broad stripes of green, yellow, gray, red, or brown. *Egyptian jasper* consists of these colors in irregular concentric zones, and occurs in nodules, which are often cut across and polished. *Ruin jasper* is a variety with delineations like ruins, of some brownish or yellowish shade on a darker ground. *Porcelain jasper* is nothing but a baked clay, and differs from jasper in being fusible before the blowpipe. Red felsyte resembles red jasper; but this is also fusible, and consists largely of feldspar.

Jasper admits of a high polish, and is a handsome stone for inlaid work, but is not much used as a gem.

Bloodstone or *Heliotrope.* Deep green, slightly translucent, containing spots of red, which have some resemblance to drops of blood. It contains a few per cent. of clay and iron oxide mechanically combined with the silica. The red spots are colored with iron. There is a bust of Christ in the royal collection at Paris, cut in this stone, in which the red spots are so managed as to represent drops of blood.

Lydian Stone, Touchstone, Basanite. Velvet-black and opaque, and used, on account of its hardness and black color, for trying the purity of the precious metals; this is done by comparing the color of the mark left on it with that of an alloy of known character. The effect of acids upon the mark is also noted.

Besides the above there are other varieties arising from structure.

Tabular Quartz. Consists of thin plates, either parallel or crossing one another and leaving large open cells.

Granular Quartz. A rock, consisting of quartz grains compactly cemented. The colors are white, gray, flesh-red, yellowish or reddish-brown. It is a hard siliceous sandstone. Ordinary sandstone often consists of nearly pure quartz.

Pseudomorphous Quartz. Quartz under the forms of calcite, barite, fluorite or other mineral. Shells, corals, etc., are sometimes found converted into quartz by the ordinary process of petrifaction.

Silicified Wood. Petrified wood often consists of quartz, quartz having taken the place of the original wood. Some specimens are petrified with chalcedony or agate.

Penetrating substances. Quartz crystals are sometimes penetrated by other minerals. Rutile, asbestus, actinolite, topaz, tourmaline, chlorite and epidote, are some of these substances. The rutile often looks like needles or fine hairs of a brown color passing through in every direction. They are cut for jewelry, and in France pass by the name of *Flèches d'amour* (love's arrows). The crystals of Herkimer County, N. Y., often contain a kind of black coal. Other crystals contain cavities filled with some fluid, as water, naphtha, or liquid carbonic acid, or with minute crystals.

Obs. Quartz is an essential constituent of granite, gneiss, mica schist, and many other common rocks, and the chief or only constituent of many sandstones, and of the sands of most sea-shores. Fine quartz crystals occur in Herkimer County, New York, at Middlefield, Little Falls, Salisbury and Newport, in the soil and in cavities in a sandstone. The beds of iron ore at Fowler and Hermon, St. Lawrence County, afford dodecahedral crystals. Diamond Island, Lake George, Pelham and Chesterfield, Mass., Paris and Perry, Me., Meadow Mt., Md., and Hot Springs, Arkansas, are other localities. *Rose quartz* is found at Albany and Paris, Me., Acworth, N. H., and Southbury, Conn.; *smoky quartz* at Goshen, Mass.; Paris, Me.; in North Carolina; at Pike's Peak, Colorado, and elsewhere; *amethyst* at Bristol, R. I., and Keweenaw Point, Lake Superior; *chalcedony* and *agates* of moderate beauty near Northampton, and along the trap of the Connecticut Valley—but finer near Lake Superior, upon some of the Western rivers, and in Oregon; *chrysoprase* occurs at Belmont's lead mine, St. Lawrence County, N. Y., and a green quartz (often called chrysoprase) at New Fane, Vt., along with fine drusy quartz; *red jasper* occurs on the banks of the Hudson at Troy; *yellow jasper* is found with chalcedony at Chester, Mass.; *Heliotrope* occupies veins in slate at Bloomingrove, Orange County, N. Y.

Switzerland, Dauphiny, Piedmont, the Carrara quarries, and numerous other foreign localities furnish fine crystals.

Opal.

Compact and amorphous; also in reniform and stalactitic shapes; also earthy. Presents internal reflections, often of several colors in the finest varieties, exhibiting, when turned in the hand, a rich play of colors of delicate shades. White, yellow, red, brown, green and gray are some of the shades that occur, and impure varieties are dark and opaque. Lustre subvitreous. H.=5·5–6·5. G.=1·9–2·3.

Composition. Opal consists of silica, like quartz; but it is silica in a different molecular state, the hardness and specific gravity being less; and, besides this, it is soluble in a strong alkaline solution, especially if heated. It usually contains a few per cent. of water—amounting in some kinds to 12 per cent.; but the water is not generally regarded as an essential constituent.

VARIETIES.

Precious Opal. External color usually milky, but within there is a rich play of delicate tints. This variety forms a gem of rare beauty. A large mass in the imperial cabinet of Vienna weighs seventeen ounces, and is nearly as large as a man's fist, but contains numerous fissures and is not entirely disengaged from the matrix. This stone was well known to the ancients and highly valued by them. They called it *Paideros*, or *Child Beautiful as Love*. The noble opal is found near Cashau in Hungary, and in Honduras, South America; also on the Faroe Islands.

Fire Opal, Girasol. An opal with yellow and bright hyacinth or fire-red reflections. It comes from Mexico and the Faroe Islands.

Common Opal, Semiopal. Common opal has the hardness of opal and is easily scratched by quartz, a character which distinguishes it from some siliceous stones often called semiopal. It has sometimes a milky opalescence, but does not reflect a play of colors. The lustre is slightly resinous, and the colors are white, gray, red, yellow, bluish, greenish to dark grayish-green. Translucent to nearly opaque. Phillips found nearly 8 per cent. of water in one specimen.

Hydrophane. This variety is opaque white or yellowish when dry, but becomes translucent and opalescent when immersed in water.

Cacholong. Opaque white, or bluish white, and usually associated with chalcedony. Much of what is so called is nothing but chalcedony; but other specimens contain water, and are allied to hydrophane. It contains also a little alumina and adheres to the tongue. It was first brought from the river Cach in Bucharia.

Hyalite, Muller's Glass. A glassy transparent variety, occurring in small concretions and occasionally stalactitic. It resembles somewhat a transparent gum arabic. *Composition,* Silica 92·00, water 6·33 (Bucholz).

Menilite. A brown opaque variety, in compact reniform masses, occasionally slaty. *Composition,* Silica 85·5, water 11·0 (Klaproth). It is found in slate at Menil Montant, near Paris.

Wood Opal. An impure opal, of a gray, brown or black color, having the structure of wood, and looking much like common silicified wood. It is wood petrified with a hydrated silica (or opal), instead of pure silica, and is distinguished by its lightness and inferior hardness. Specific gravity, 2.

Opal Jasper. Resembles jasper in appearance, and contains a few per cent. of iron ; but it is not so hard, owing to the water it contains.

Siliceous Sinter has often the composition of opal, though sometimes simply quartz. The name is given to a loose, porous siliceous rock usually of a grayish color. It is deposited around the Geysers of Iceland and the Yellowstone Park, in cellular or compact masses, sometimes in fibrous, stalactitic, or cauliflower-like shapes. It is often called *geyserite.* *Pearl sinter,* or *fiorite,* occurs in volcanic tufa in smooth and shining globular, botryoidal masses, having a pearly lustre.

Float Stone. A variety of opal having a porous and fibrous texture, and hence so light that it will float on water. It occurs in concretionary or tuberose masses, which often have a nucleus of quartz.

Tripolite, or *Infusorial Earth.* A white or grayish-white earth, made mainly of siliceous secretions of microscopic plants called Diatoms. It forms beds of considerable extent, and often occurs beneath peat. It is used as a polishing powder ; also to mix with nitroglycerine and make dynamite ; and, owing to its poor conduction of heat, it is applied as a protection to steam boilers and pipes.

Tabasheer is a siliceous aggregation found in the joints of the bamboo in India. It contains several per cent. of water, and has nearly the appearance of hyalite.

Diff. Infusibility before the blowpipe is the best character for distinguishing opal from pitchstone, pearlstone, and other species it resembles. The absence of anything like cleavage or crystalline structure is another characteristic. Its inferior hardness and specific gravity separates it from quartz.

Obs. Hyalite occurs sparingly at the Phillips ore bed, Putnam County, N. Y., and in Burke and Scriven counties, Georgia. In Washington County, Ga., good fire opal is obtained. The Suanna Spring in Georgia affords small quantities of siliceous sinter. Tripolite occurs in Maine, New Hampshire, Nevada, California, and elsewhere.

Tridymite. Pure silica, like quartz and opal, with very nearly the hardness and specific gravity of opal, but occurring in tabular hexagonal prisms, which are twins under the triclinic system. If not crystallized opal, it is a _third_ state of SiO_2. It occurs in trachytic and some other volcanic rocks. _Asmanite_ is from a meteorite, and may be the same as tridymite.

Jenzschite. Silica, SiO_2, in, it is supposed, a _fourth_ state, it resembling opal in aspect and in solubility in alkaline solutions, but having the specific gravity of quartz, or 2·6. From Hüttenberg in Carinthia, resembling a white cachalong ; from near Weissig ; Regensberg ; and in Brazil.

Melanophlogite. Colorless cubes consisting of silica, with a little sulphuric trioxide and water. On sulphur from Girgenti, Sicily.

II. SILICATES.

The silicates are here divided into the *anhydrous* and the *hydrous*.

In part of the anhydrous silicates, the combining value (or quantivalence, see page 77) of the silicon is to that of the basic elements as 2 to 1; in another part, as 1 to 1; and in a third division, as less-than-1 to 1. On this ground the mineral silicates may be arranged in three groups, named respectively: I. BISILICATES; II. UNISILICATES; and III. SUBSILICATES.

In the *Bisilicates*, one molecule of silicon is combined with *one* molecule of an element in the protoxide state, as Mg, Ca, Fe, etc., or one-third of a molecule of an element in the sesquioxide state, as **Al**, **Fe**, **Mn**, etc.; or, what is the same thing, 3 molecules of silicon, with 3 of an element in the protoxide state, or 1 of an element in the sesquioxide state. The general formulas of such compounds is hence RO_3Si, or $\mathbf{R}O_9Si_3$, or, if elements in both the protoxide and sesquioxide state are present, $(R_3\mathbf{R})O_9Si_3$, as explained on page 81.

In the *Unisilicates*, one molecule of silicon is combined with two of an element in the protoxide state, that is, for example, Mg_2, Ca_2, Fe_2; or with two-thirds of a molecule in the sesquioxide state, that is, two-thirds of **Al**, **Fe**, **Mn**. The formula of these silicates is hence R_2O_4Si, or $\mathbf{R}_{\frac{2}{3}}O_4Si$, or, in order to remove the fraction in the last, $\mathbf{R}_2O_{12}Si_3$; which becomes, when elements in the protoxide and sesquioxide state are both present, $(R_3, \mathbf{R})_2O_{12}Si_3$.

Among the species referred to the Unisilicates there are some that vary from the unisilicate ratio. This occurs especially in species in which an alkali is present, as in the feldspars, micas, and scapolites.

The *Subsilicates* vary in the proportion of the silicon to the basic elements, and graduate into the unisilicates.

The same three grand divisions exist more or less satisfactorily among the hydrous silicates.

A. ANHYDROUS SILICATES.

I. BISILICATES.

The bisilicates, when the base is in the protoxide state, and hence have the general formula $\mathrm{R\,O_3\,Si}$, are resolved *in analyses* into protoxides and silica in the ratio of $\mathrm{1\,R\,O}$ to $\mathrm{1\,Si\,O_2}$, in which, as the term *bisilicate* implies, the oxygen of the silica is twice that of the protoxides. If the base is in both the protoxide and sesquioxide states, giving the formula $\mathrm{R_3,\mathbf{R}\,O_9\,Si_3}$, the mineral is resolved in analyses into protoxides, sesquioxides and silica. If the ratio of the protoxides to sesquioxides is 1 : 1, the formula will become $\mathrm{\frac{1}{2}R_3\,\frac{1}{2}\mathbf{R}\,O_9\,Si_3}$; and analyses give then, for the oxides and silica $\mathrm{3\,RO,\ 1\,\mathbf{R}\,O_3\ 6\,Si\,O_2}$.

Among the following bisilicates the species from enstatite to spodumene and amphibole make a natural group called the hornblende, or hornblende and augite group. They are closely related in composition and also in crystallization. The cleavage prism is rhombic, and has either an angle of about 124½° or of about 87°; and the former of these two rhombic prisms has just twice the breadth of the other; that is, if the lateral axis from the front to the back edge in each be taken as unity, the other lateral axis is twice as long in the prism of 124½° as it is in that of 87°. The forms are either trimetric, monoclinic or triclinic; and yet the close relations just stated exist between them. Enstatite is a magnesium or magnesium and iron species; wollastonite, a calcium species; rhodonite, a manganese species; pyroxene and hornblende contain calcium with magnesium or iron; spodumene contains lithium and aluminum, aluminum replacing the elements that in other species are in the protoxide state.

Enstatite.

Trimetric. $I \wedge I = 88° 16'$. Prismatic cleavage easy. Usually possesses a fibrous appearance on the cleavage surface. Also massive and lamellar.

Color, grayish, yellowish or greenish-white, or brown. Lustre pearly; often metalloidal in the bronzite variety. H. 5·5. G. 3·1–3·3.

Composition. $Mg\,O_3\,Si$ = Silica 60, magnesia 40. B.B. infusible, and insoluble. *Bronzite* has a portion of the magnesium replaced by iron.

Diff. Resembles amphibole and pyroxene, but is infusible, and trimetric in crystallization.

Obs. Occurs in the Vosges; Moravia; Bavaria; Baste, in the Hartz; Leiperville and Texas, Pa.; Brewster's, N. Y.

Hypersthene is very near bronzite in crystalline form and in composition. It contains a larger percentage of iron, and on being heated B.B. on charcoal it becomes magnetic. Occurs at St. Paul's Island, in Labrador; Isle of Skye; in Greenland; Norway, etc.

Wollastonite.—Tabular Spar.

Monoclinic. Rarely in oblique flattened prisms. Usually massive, cleaving easily in one direction, and showing a lined or indistinctly columnar surface, with a vitreous lustre inclining to pearly.

Usually white, but sometimes tinged with yellow, red or brown. Translucent, or rarely subtransparent. Brittle. H.=4·5–5. G.=2·75–2·9.

Composition. $Ca\,O_3\,Si$ = Silica 52, lime 48 = 100. B.B. fuses with difficulty to a subtransparent, colorless glass; in powder decomposed by hydrochloric acid, and the solution gelatinizes on evaporation; often effervesces when treated with acid on account of the presence of calcite.

Diff. Differs from asbestus and tremolite in its more viterous appearance and fracture, and by its gelatinizing in acid; from the zeolites by the absence of water, which all zeolites give in a closed tube; from feldspar in the fibrous appearance of a cleavage surface and the action of acids.

Obs. Usually found in granite or granular limestone; occasionally in basalt or lava. Occurs in Ireland at Dunmore Head; at Vesuvius and Capo di Bove; in the Hartz; Hungary; Sweden; Finland; Norway.

At Willsboro', Lewis, Diana, and Roger's Rock, N. Y., of a white color, along with garnet; at Boonville, in bowlders with garnet and pyroxene; Grenville, Lower Canada; in Bucks County, Pennsylvania; at Keweenaw Point, Lake Superior. *Edelforsite* is impure wollastonite.

Pyroxene.—Augite.

Monoclinic., $I \wedge I=87° 5'$; cleavage perfect parallel with the sides of this prism, and also distinct parallel with the

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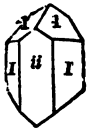

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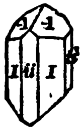

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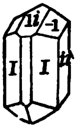

diagonals. Usually in thick and stout prisms, of 4, 6 or 8 sides, terminating in two faces meeting at an edge. $I \wedge i\text{-}\breve{i}=133° 33'$, $I \wedge i\text{-}\grave{i}=136° 27'$; $1 \wedge 1=120° 32'$. Massive varieties of a coarse lamellar structure; also fibrous, fibres often very fine and often long capillary. Also granular, usually in coarse granular and friable masses; grains usually angular; sometimes round; also compact massive.

Colors green of various shades, verging to white on one side and brown and black on the other, passing through *blue* shades, but *not yellow*. Lustre vitreous, inclining to resinous or pearly; the latter especially in fibrous varieties. Transparent to opaque. H.=5–6. G.=3·2–3·5.

Composition. RO_3Si; in which R may be Ca, Mg, Fe, Mn, and sometimes Zn, K_2, Na_2, these bases replacing one another without changing the crystalline form, of which two or more are usually present; the first three are most common. Calcium is always present. The following is an analysis of a typical variety: Silica 55·0, lime 23·5, magnesia 16·5, manganese protoxide ·5, iron protoxide 4·5=100. Fuses B.B., but its fusibility varies with the composition, and the ferriferous varieties are most fusible. Insoluble in acids.

Diff. Its crystalline form, and its ready cleavage in two planes nearly at right angles to one another, are the best characters for its determination.

VARIETIES.—The varieties may be divided into three sections—the light colored, the dark colored, and the thin foliated.

I. *Malacolite* or *white augite* is a calcium magnesium pyroxene, and includes white or grayish-white crystals or crystalline masses. *Diopside,* of the same composition, occurs in greenish-white or grayish-green crystals, and cleavable masses cleaving with a bright smooth surface. *Sahlite* contains iron in addition, and is of a more dingy green color, has less lustre and coarser structure than diopside, but is otherwise similar; named from the place Sahla, where it occurs. *Fassaite* contains a little alumina in addition to the elements of sahlite, and is found in crystals of rich green shades and smooth and lustrous exterior. The name is derived from the foreign locality Fassa. *Coccolite* is a general name for granular varieties, derived from the Greek *coccos, grain.* The green is called *green coccolite,* the white, *white coccolite.* The specific gravity of these varieties varies from 3·25 to 3·3.

Asbestus. This name includes *fibrous* varieties of both pyroxene and hornblende; it is more particularly noticed under the latter species, as pyroxene is rarely asbestiform.

II. *Augite* includes the black and greenish-black crystals, which contain a larger percentage of iron, or iron and magnesium, and which mostly present the form in figure 1. Specific gravity 3·3–3·4. This is the common pyroxene of eruptive rocks. *Hedenbergite,* an iron-calcium pyroxene, is a greenish-black opaque variety, in cleavable masses affording a greenish-brown streak; specific gravity 3·5. *Polylite, Hudsonite,* and *Jeffersonite,* fall here; the last contains some zinc oxide. These varieties fuse more easily than the preceding, and the globule obtained is colored black by the iron oxide.

III. *Diallage* is a thin-foliated variety, often occurring imbedded in serpentine and some other rocks. It differs from bronzite and hypersthene in crystalline form, and in being fusible.

Obs. Pyroxene is one of the most common minerals. It occurs in almost all basic eruptive rocks, like doleryte, as an essential constituent, and is frequently met with in rocks of other kinds; common also in granular limestone. In basalt the crystals are generally small and black or greenish black. In the other rocks, they occur of all the shades of color given, and of all sizes to a foot or more in length. One crystal from Orange County, measured 6 inches in length, and

10 in circumference. White crystals occur at Canaan, Conn., Kingsbridge, New York County, and the Sing Sing quarries, Westchester County, N. Y.; in Orange County at several localities; green crystals at Trumbull, Conn., at various places in Orange County, N. Y., Roger's Rock and other localities in Essex, Lewis, and St. Lawrence counties. Dark green or black crystals are met with near Edenville, N. Y., Diana, Lewis County. Jeffersonite occurs at Franklin, in N. J. Green coccolite is found at Roger's Rock, Long Pond, and Willsboro', N. Y.; black coccolite, in the forest of Dean, Orange County, N. Y. Diopside, at Raymond and Rumford, Me., Hustis's farm, Phillipstown, N. Y.

Pyroxene was thus named by *Haüy* from the Greek *pur*, fire, and *xenos*, stranger, in allusion to its occurring in lavas, where, according to a mistake of Haüy, it did not belong. The name *Augite* is from the Greek *auge*, lustre.

Ægerite. Black to greenish black in color. It is a pyroxene containing nearly 10 per cent. of soda, and much iron sesquioxide. From near Brevig in Norway; Hot Springs, Arkansas.

Acmite. In long highly-polished prisms, of a dark-brown or reddish-brown color, with a pointed extremity, penetrating granite, near Kongsberg in Norway. $I \wedge I=86^\circ 56'$, resembles pyroxene. Contains over 12 per cent. of soda. Fuses easily before the blowpipe.

Babingtonite. Resembles some varieties of pyroxene. It occurs in greenish-black splendent crystals in quartz at Arendal in Norway.

Uralite. Has the form of pyroxene but cleavage of hornblende.

Rhodonite.—Manganese Spar, Fowlerite.

Triclinic, but very nearly isomorphous with pyroxene. Usually massive, the cleavage often indistinct.

Color reddish, usually deep flesh-red; also brownish, greenish, or yellowish, when impure; very often black on the surface; streak uncolored. Lustre vitreous. Transparent to opaque. Becomes black on exposure. H.=5·5–6·5. G.=3·4–3·7.

Composition. $\mathrm{Mn\,O_3\,Si}$ = Silica 45·9, manganese protoxide 54·1=100. It usually contains a little iron and lime replacing the manganese. Becomes dark brown when heated, and, with borax in the outer flame, gives a deep violet color to the bead while hot, and a red-brown when cold.

Diff. Resembles somewhat a flesh-red feldspar, but differs in greater specific gravity, in blackening on long exposure, and in the glass with borax.

Obs. Occurs in Sweden, the Hartz, Siberia, and elsewhere. In the United States it is found, in masses, at Plainfield and Cummington, Mass.; also abundantly at Hinsdale, and on Stony Mountain, near Winchester, N. H.; at Blue Hill Bay, Me. The black exterior is a more or less pure hydrated oxide of manganese.

Rhodonite may be used in making a violet-colored glass, and also for a colored glazing on stoneware. It receives a high polish and is sometimes employed for inlaid work.

Spodumene.

Monoclinic. $I \wedge I = 87$, being near the angle of pyroxene. Cleavage easy, parallel to I and i-i. Surface of cleavage pearly. Color grayish or greenish. Translucent to subtranslucent. H.=6·5–7. G.=3·1–3·19.

Composition. $(R_3, Al) O_9 Si_3$, in which R is lithium and equals Li_2, and $3 Li_2$ is to Al as 1 : 4. This corresponds to silica 64·2, alumina 29·4, lithia 6·4=100. B.B. becomes white and opaque, fuses, swells up, and imparts to the flame the purple-red flame of lithia. Unaffected by acids.

Diff. Resembles somewhat feldspar and scapolite, but has a higher specific gravity and a more pearly lustre, and affords rhombic prisms by cleavage. Its lithia reaction is its most characteristic test.

Obs. Occurs in granite at Goshen; also at Chesterfield, Norwich and Sterling, Mass.; at Windham, Me.; at Brookfield and Branchville, Ct.; at Uton, in Sweden; Sterzing in the Tyrol; and at Killiney Bay, near Dublin. *Cymatolite* and *Killinite* are results of its alteration.

This mineral is remarkable for the *lithia* it contains.

Petalite.

Monoclinic. Usually in imperfectly cleavable masses; most prominent cleavage angle 141° 30′. Color white or gray, or with pale-reddish or greenish shades. Lustre vitreous to sub-pearly. Translucent. H.=6–6·5. G.=2·5.

Composition. Contains lithia like spodumene, and gives the percentage—Silica 77·9, alumina 17·7, lithia 3·1, soda 1·3=100. Phosphoresces when gently heated. Fuses with difficulty on the edges. Gives the reaction of lithia like spodumene.

Diff. Its lithia reaction allies it to spodumene, but it differs from that mineral in lustre, specific gravity, and greater fusibility.

Obs. From Utö, Sweden; also from Elba (*Castor* or *Castorite*).

Amphibole.—Hornblende.

Monoclinic. $I \wedge I = 124° 30'$. Cleavage perfect parallel with *I*. Often in long, slender, flat rhombic prisms (fig. 2), breaking easily transversely; also often in 6-sided prisms, with oblique extremities. Frequently columnar, with a bladed structure; long fibrous, the fibres coarse or fine and often like flax, with a pearly or silky lustre; also lamellar; also granular, either coarse or fine.

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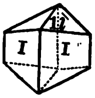

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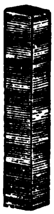


3.

Colors from white to black, passing through bluish-green, grayish-green, green, and brownish-green shades, to black. Lustre vitreous, with the cleavage face inclining to pearly. Nearly transparent to opaque. H.=5–6. G.=2·9–3·4.

Composition. $R O_3 Si$, as for pyroxene. R may correspond to two or more of the basic elements Mg, Ca, Fe, Mn, Na_2, K_2, the first three being most common.) Aluminum is very often present in amphibole, replacing a portion of the silicon. The blowpipe characters are like those of pyroxene. It fuses, but the fusibility varies indefinitely, being easiest in the black varieties.

Diff. It is distinguished by the very ready cleavages parallel to a prism of 124½°, while pyroxene cleaves at nearly a right angle (87° 5′).

This species, like pyroxene, has numerous varieties, differing much in external appearance, and arising from the same causes—isomorphism and crystallization.

The following are the most important varieties:

I. LIGHT-COLORED VARIETIES.

Tremolite, Grammatite. Tremolite comprises the white and grayish crystallizations which usually occur in blades or long crystals penetrating the gangue or aggregated into coarse columnar forms. Sometimes nearly transparent. G.=2·9. Formula $(Ca, Mg) O_3 Si$=Silica 57·70, magnesia 28·85, lime 13·45=100. The name is from the foreign locality, *Tremola*, in Switzerland.

Actinolite. The light-green varieties. It is a magnesium-calcium-iron amphibole. *Glassy actinolite* includes the bright glassy crystals, of a rich green color, usually long and slender, and penetrating the gangue like tremolite. *Radiated actinolite* includes olive-green masses, consisting of aggregations of coarse acicular fibres, radiating or divergent. *Asbestiform actinolite* resembles the radiated, but the fibres are more delicate. *Massive actinolite* consists of angular grains instead of fibres. G.=3·0–3·1. The name actinolite alludes to the radiated structure of some varieties, and is derived from the Greek, *aktin*, a ray of the sun.

Asbestus. In slender fibres easily separable, and sometimes like flax. Either green or white. *Amianthus,* includes fine silky varieties. (Much so called is serpentine; serpentine is hydrous, and is thereby easily distinguished.) *Ligniform asbestus* is compact and hard; it occurs of brownish and yellowish colors, and looks somewhat like petrified wood. *Mountain leather* occurs in thin, tough sheets, looking and feeling a little like kid leather; it consists of interlaced fibres of abestus, and forms thin seams between layers or in fissures of rocks. *Mountain cork* is similar, but is in thicker masses; it has the elasticity of cork, and is usually white or grayish white.

The preceding light-colored varieties contain little or no alumina or iron.

Composition of glassy actinolite: Silica 59·75, magnesia 21·1, lime 14·25, protoxide of iron 3·9, protoxide of manganese 0·3, hydrofluoric acid 0·8 (Bonsdorf).

Nephrite is a very tough compact variety, related to tremolite. Color light-green or blue. It breaks with a splintery fracture and glistening lustre. H.=6–6·5. G.=3. It is a magnesium-calcium amphibole. Nephrite is made into images, and was formerly worn as a charm. It was supposed to be a cure for diseases of the kidney, whence the name, from the Greek, *nephros,* kidney. In New Zealand, China and Western America, it is carved by the inhabitants, or polished down into various fanciful shapes. It is called jade; but the aluminum-sodium silicate, called jadeite, is the stone most highly prized of all those that are called jade. Much of the mineral from China called jade is prehnite.

II. DARK-COLORED VARIETIES.

Cummingtonite is a magnesium-iron amphibole. Color gray or brown; usually fibrous. Named from the locality where found, Cummington, Mass.

Pargasite. Dark-green crystals, short and stout (resembling fig. 4), with bright lustre, of which Pargas in Finland is a noted locality. G.=3·11.

Composition. Silica 45·5, alumina 14·9, iron protoxide 8·8, manganese protoxide 1·5, magnesia 14·4, lime 14·9=100.

Hornblende. Black and greenish-black crystals and massive specimens. Often in slender crystallizations like actinolite ; also short and stout like figs. 4 and 5, the latter more especially. It contains a large percentage of iron oxide, and to this owes its dark color. It is a tough mineral, as is implied in the name it bears. This character, however, is best seen in the massive specimens.) Pargasite and hornblende contain both alumina and iron.

Composition of a hornblende : Silica 48·8, alumina 7·5, magnesia 13·6, lime 10·2, iron protoxide 18 8, manganese protoxide 1·1=100.

Obs. Hornblende is an essential constituent of certain rocks, as syenyte, dioryte and hornblende schist. Actinolite is usually found in magnesian rocks, as talc, steatite or serpentine; tremolite in granular limestone and dolomite ; asbestus in the above rocks and also in serpentine. Black crystals of hornblende occur at Franconia, N. H., Chester, Mass., Thomastown, Me., Willsboro', N. Y., in Orange County, N. Y., and elsewhere. Pargasite occurs at Phippsburg and Parsonsfield, Me.; glassy actinolite, in steatite or talc, at Windham, Readsboro', and New Fane, Vt., Middlefield and Blandford, Mass.; and radiated varieties at the same localities and many others. Tremolite and gray hornblende occur at Canaan,. Ct., Lee, Newburgh, Mass., in Thomaston and Raymond, Me., Dover, Kingsbridge, and in St. Lawrence County, N. Y. ; at Chestnut Hill, Penn. ; at the Bare Hills, Md. Asbestus at many of the above localities ; also Brighton and Sheffield, Mass. ; Cotton Rock and Hustis's farm, Phillipstown, N. Y., near the Quarantine, Richmond County, N. Y. Mountain leather is met with at Brunswick, N. J. *Edenite,* a white aluminous kind, occurs at Edenville, N. Y.

Asbestus is the only variety of this species of any use in the arts. The flax-like variety is sometimes woven into fire-proof textures. Its incombustibility and slow conduction of heat render it a complete protection against the flames. It is often made into gloves. A fabric when dirty, need only be thrown into the fire for a few minutes to be white again. The ancients, who were acquainted with its properties, are said to have used it for napkins, on account of the ease with which it was cleaned. It was also the wick of the lamps in the ancient temples; and because it maintained a perpetual flame without being consumed, they named it *asbestos*, unconsumed. It is now used for the same purpose by the natives of Greenland. The name amianthus alludes to the ease of cleaning it, and it is derived from *amiantos*, undefiled. Asbestus is extensively used for lining iron safes, and for protecting steam pipes and boilers. The best locality for collecting asbestus in the United States is that near the Quarantine, in Richmond County, N. Y.

Anthophyllite is related in the angle of its prism to hornblende, but is trimetric. In composition and its infusibility before the blowpipe, it is near bronzite. B.B. it becomes magnetic. From Kongsberg in Norway, and near Modum. *Kupfferite* has the hornblende angle, but in composition it is like enstatite, being a magnesium silicate.

Arfvedsonite. Near hornblende; but contains over 10 per cent. of soda, like acmite.

Crocidolite. Near arfvedsonite in composition. A lavender-blue or leek-green fibrous mineral from Orange River, South Africa, and from the Vosges; also from Rhode Island (A. H. Chester).

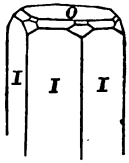
Gastadite. A dark blue to azure-blue mineral related to amphibole, from the valleys of Aosta and Locano.

Glaucophane. A bluish mineral with the amphibole angle, from the Island of Syra. *Wichtisite* may be the same mineral.

Milarite. Trimetric, of the composition $(KH)Ca_2\,Al\,O_{32}\,Si_{12}$; the quantivalent ratio for bases and silica 1 : 4; being therefore a quatersilicate instead of a bisilicate.

Beryl.—Emerald.

Hexagonal. In hexagonal prisms, usually without regular terminations. Cleavage basal, not very distinct. Rarely massive.



Color green, passing into blue and yellow; color rather pale, excepting the deep and rich green of the emerald. Streak uncolored. Lustre vitreous; sometimes resinous. Transparent to subtranslucent. Brittle. H. = 7·5–8. G. = 2·65–2·75.

VARIETIES. The *emerald* is the rich green variety; it owes its color to the presence of chromium. *Beryl* includes the paler varieties, which are colored by oxide of iron. *Aqua*

[illegible]

marine includes clear beryls of a sea-green, or pale-bluish or bluish-green tint.

Composition. $Be_3Al\,O_{18}\,Si_6$=Silica 66·8, alumina 19·1, glucina 14·1=100. *Emerald* contains less than one per cent. of chromium oxide. B.B. becomes clouded, but does not fuse; at a very high temperature the edges are rounded. Unacted upon by acids.

Diff. The hardness distinguishes this species from apatite; and this character, and also the form of the crystals, from green tourmaline.

Obs. The finest emeralds come from Muso, near Santa Fé in New Grenada, where they occur in dolomite. A crystal from this locality, 2¼ inches long and about 2 inches in diameter, is in the cabinet of the Duke of Devonshire; it weighs 8 oz. 18 dwts., and is a regular hexagonal prism. A more splendid specimen, but weighing only 6 oz., in the possession of Mr. Hope, of London, cost £500. Emeralds of less beauty, but of gigantic size, occur in Siberia. One specimen in the royal collection of Russia measures 4½ inches in length and 12 in breadth, and weighs 16¾ pounds troy. Another is 7 inches long and 4 broad, and weighs 6 pounds. Mount Zalora in Upper Egypt affords a less distinct variety.

The finest beryls (*aquamarines*) come from Siberia, Hindostan and Brazil. One specimen belonging to Dom Pedro is as large as the head of a calf, and weighs 225 ounces, or more than 18½ pounds troy; it is transparent and without a flaw. In 1827 a fine aquamarine, weighing 35 grams, was found in Siberia, which is said to have been valued at 600,000 francs.

In the United States, beryls of enormous size have been obtained, but seldom transparent crystals. They occur in granite or gneiss. One hexagonal prism from Grafton, N. H., weighs 2,900 pounds and measured 4 feet in length, with one diameter of 32 inches and another of 22; its color was bluish green, excepting a part at one extremity, which was dull green and yellow. At Royalston, Mass., one crystal has been obtained a foot long, and pellucid crystals are sometimes met with. Haddam, Conn., has afforded fine crystals (see the figure). Other localities are Barre, Fitchburg, Goshen, Mass.; Albany, Norwich, Bowdoinham and Topham, Me.; Wilmot, N. H.; Monroe, Portland, Haddam, Conn.; Leiperville, Penn.

Phenacite. A beryllium-silicate, rhombohedral in crystallization. From the Urals, and Durango in Mexico.

Eudialyte. A pale rose-red mineral, from West Greenland, occurring in rhombohedral crystals, and containing 15·6 per cent. of zirconia. *Eucolite* is a related species from Norway.

Pollucite. An isometric *cæsium* silicate, white, vitreous in lustre, with G.=2·868. Analysis afforded Rammelsberg Silica 48·15, alumina 16·31, potash 0·47, soda 2·48, cæsium oxide 30·00, water 2·59=100, giving very nearly the bisilicate formula $H_2Cs_2\not{\text{Al}}\,O_{20}\,Si_5$. From Elba.

II. UNISILICATES.

For the convenience of the student, the general formulas of the regular Unisilicates are here re-stated. They are as follows:

If the base is in the protoxide state alone, the formula is R_2O_4Si, in which R stands for Ca, Mg, Fe, Mn, K_2, Na_2, or Li_2, or other mutually replaceable base. In analyses, the mineral is resolved into protoxides and silica, in the ratio of 2 RO to SiO_2, in which the oxygen of the silica equals that of the basic portion.

If the base is in the sesquioxide state alone, the formula is $\text{Ɍ}_2\,O_{12}\,Si_3$, in which Ɍ may stand for $\not{\text{Al}}$, $\not{\text{Fe}}$, or $\not{\text{Mn}}$, etc. Here the mineral is resolved, in analyses, into sesquioxides and silica in the ratio of $2\,\text{Ɍ}O_3$ to $3\,Si\,O_2$, in which the oxygen of the silica again equals that of the basic portion.

If the basic portion is partly in the protoxide state and partly in the sesquioxide, the formula, in its most general form, is $(R_3, \text{Ɍ})_2\,O_{12}\,Si_3$. In this formula the ratio of R_3 to Ɍ is not stated. If the ratio is 1 : 1, the formula becomes $R_3\text{Ɍ}\,O_{12}\,Si_3$, or its equivalent $(\frac{1}{2}R_3\,\frac{1}{2}\text{Ɍ})_2\,O_{12}\,Si_3$. In a case like this last, the mineral is resolved, in analyses, into protoxides, sesquioxides and silica, in the ratio of $3RO : \text{Ɍ}\,O_3 : 3\,Si\,O_2$, in which again the oxygen of the bases equals that of the silica.

If the proportion of R_3 to Ɍ is 1 : 3, this corresponds to $\frac{1}{3}R_3 : \text{Ɍ}$, or, its equivalent, $R : \text{Ɍ}$; and hence the formula in its general form will be $R\text{Ɍ}\,O_8\,Si_2$.

If the base is in the dioxide state, the formula becomes RO_4Si, an example of which occurs in zircon, whose formula is ZrO_4Si.

There are several natural groups of species among the Unisilicates.

GROUP.	STATE OF BASES.	CRYSTALLIZATION.
1. Chrysolite group,	protoxide,	Trimetric.
2. Willemite group,	protoxide,	Hexagonal.
3. Garnet group,	protoxide and sesquioxide,	Isometric.
4. Zircon group,	dioxide,	Dimetric.
5. Idocrase and Scapolite groups,	protox. and sesquiox.	Dimetric.
6. Mica group,	protox. and sesquiox.	Trimetric; plane angle of base, 120°; micaceous.
7. Feldspar group,	protox. and sesquiox.	Monoclinic or triclinic, $I \wedge I$ nearly 120°.

In the Scapolite, Mica and Feldspar groups part of the species contain an alkaline metal in the basic portion, and such kinds have generally an excess of silica. Among the feldspars, the species containing only calcium as the protoxide base, is a true Unisilicate. In the others, there is an excess directly proportional to the increase of the soda, as explained beyond.

Chrysolite.—Olivine.

Trimetric. In rectangular prisms having cleavage parallel with *i-ĭ*. Usually in imbedded grains of an olive-green color, looking like green bottle-glass. Also yellowish green. Transparent to translucent. H.=6–7. G.=3·3–3·5. Looks much like glass in the fracture, except in its having cleavage.

Composition. $(Mg, Fe)_2O_4Si$=, for a common variety, Silica 41·39, magnesia 50·90, iron protoxide 7·71=100. The amount of iron is variable. B.B. whitens but is infusible. With borax forms a yellow bead owing to the iron present. Decomposed by hydrochloric acid, and the solution gelatinizes when evaporated. *Hyalosiderite* is a very ferruginous variety which fuses B.B.

Diff. Distinguished from green quartz by its occurring disseminated in basaltic rocks, which never so occurs; and in its cleavage. From obsidian or volcanic glass it differs in its infusibility.

Obs. Occurs as a rock formation; also disseminated through basalt and other eruptive rocks, and is a characteristic mineral of some varieties of them. Has been found in New Hampshire, Canada, and elsewhere. As a rock it occurs in North Carolina, and Pennsylvania. It also occurs in many meteorites. *Boltonite,* from limestone at Bolton, Mass., is a variety of chrysolite.

Sometimes used as a gem, but it is too soft to be valued, and is not delicate in its shade of color.

Forsterite is a magnesian chrysolite $Mg_2 O_4 Si$; *Fayalite,* an iron chrysolite, $Fe_2 O_4 Si$; *Monticellite,* a calcium-magnesium, $Ca Mg_2 O_4 Si$; *Hortonolite,* an iron-magnesium chrysolite from Orange County, N. Y.; *Rœpperite,* an iron-manganese-zinc chrysolite from Stirling Hill, N. J.; *Tephroite,* a manganese chrysolite $Mn_2 O_4 Si$, from Stirling Hill, N. J.; *Knebelite,* a manganese-iron chrysolite, $MnFe O_4 Si$, from Dannemora, Sweden.

Leucophanite and *meliphanite* are species containing the element glucinum (beryllium), the former greenish yellow and G=2·97, the latter yellow and G=3·018. From Norway.

Wöhlerite contains zirconium, and also columbium; color light yellow. G=3·41.

Willemite is a zinc unisilicate, $Zn_2O_4 Si$. See page 157.

Dioptase is a copper silicate, which, making the water basic, is a unisilicate, $H_2Cu O_4 Si$. See page 141.

Friedelite is a rose-red manganese silicate of the general formula $R_2 O_4 Si$, in which R consists of manganese and hydrogen in the atomic ratio 2:1.

Helvite (Helvin). Isometric; in tetrahedral crystals. Color honey-yellow, brownish, greenish. Lustre vitreo-resinous. H.=6-6·5. G.=3·1-3·3. Contains manganese, iron, and glucinum, and some sulphur. From Saxony, and Norway.

Danalite. Isometric; in octahedral crystals. Color flesh-red to gray. Lustre vitreo-resinous. H.=5·5. G.=3·427. Contains zinc, glucinum, iron, manganese. Found disseminated through the granite at Rockport, Cape Ann, Mass., and also near Gloucester, Mass.

Eulytite is a bismuth silicate, and *Bismutoferrite* a bismuth-and-iron silicate.

Garnet.

Isometric. Common in dodecahedrons (fig. 1), also in trapezohedrons (fig. 2), and both forms are sometimes variously modified. Cleavage parallel to the faces of the dodecahedron; sometimes rather distinct. Also found massive granular, and coarse lamellar.

Color deep red to cinnamon color; also brown, black, green, emerald-green, white. Transparent to opaque. Lustre vitreous. Brittle. H.=6·5–7·5. G.=3·1–4·3.

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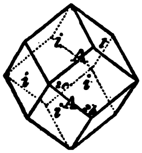

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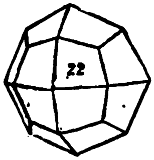

Composition and *Varieties.* The general formula for the species is $(R_3\cancel{R})_2\,O_{12}\,Si_3$; in which R may be calcium, magnesium, iron, manganese, and $\cancel{R}$ may be aluminum, iron, chromium. The varieties owe their differences to the proportions of these elements, or the substitution of one for another. Most garnets fuse easily to a brown or black glass; but the fusibility varies with the constituents, and chrome-garnet is infusible. They are not decomposed by hydrochloric acid; but if first ignited, then pulverized and treated with acid, they are decomposed, and the solution usually gelatinizes when evaporated.

There are three series among the varieties: one, that of alumina-garnet, in which the sesquioxide base is chiefly aluminum; the second, that of iron-garnet, in which the sesquioxide base is chiefly iron instead of aluminum; and third, chrome-garnet, in which it is chromium.

I. ALUMINA-GARNET.

Almandite (*Almandine*). An iron alumina-garnet, $Fe_3\,\cancel{Al}\,O_{12}\,Si_3$=Silica 36·1, alumina 20·6, iron protoxide 43·3=100. It occurs of various shades of red from ruby-red and hyacinth-red, to columbine-red and brownish red. When transparent it is called *precious* garnet; and, if not so, *common* garnet.

Grossularite (including *Cinnamon Stone*). A lime alumina-garnet, $Ca_3\,\cancel{Al}\,O_{12}\,Si_3$=Silica 40·1, alumina 22·7, lime 37·2=100, but often with some iron protoxide in place of part of the lime. The name *Grossularite* was given to a pale-green garnet, in allusion to the color, from the Latin name for gooseberry. *Cinnamon Stone* includes the cinnamon-colored variety.

Pyrope. A magnesia alumina-garnet $Mg_3Al\,O_{12}\,Si_3$. Color deep red, but varying to black and green.

Spessartite. A manganese alumina-garnet $(Mn,Fe)_3Al\,O_{12}\,Si_3$, some iron replacing part of the manganese. Color red, brownish red, hyacinth-red. A Haddam specimen afforded Seybert, Silica 35·8, alumina, 18·1, iron protoxide 14·9, manganese protoxide 31·0.

II. IRON-GARNET.

Andradite. A lime iron-garnet, $Ca_3Fe\,O_{12}\,Si_3$. Colors various, from that of almandite or common garnet, to a wine-yellow, as in *Topazolite;* green, as in *Jelletite;* and black, as in *Melanite* and *Pyreneite.*

Colophonite is a dark-red to brownish-yellow coarse granular garnet having often iridescent hues.

Aplome is a red variety. *Rothoffite* has manganese in place of part of the lime, and a yellowish-brown to reddish-brown color.

Ytter-garnet contains yttria in place of part of the lime.

Bredbergite. A lime-magnesia iron-garnet.

III. CHROME-GARNET.

Ouvarovite. An emerald-green lime chrome-garnet $(Ca, Mg)_3Fe\,O_{12}Si_3$. G.=3·41–3·42.

Diff. The vitreous lustre of fractured garnet, and its usual dodecahedral forms, are easy characters for distinguishing it.

Obs. Garnet occurs abundantly in mica schist, hornblende schist, and gneiss, and somewhat less frequently in granite and granular limestone; sometimes in serpentine; occasionally in trap, and other igneous rocks.

The best *precious garnets* are from Ceylon and Greenland; *cinnamon stone* comes from Ceylon and Sweden; *grossularite* occurs in the Wilui River, Siberia, and at Tellemarken in Norway; *green garnets* are found at Schwartzenberg, Saxony; *melanite,* in the Vesuvian lavas; *ouvarovite,* at Bissersk in Russia; *topazolite,* at Mussa, Piedmont.

In the United States, *precious garnets,* of small size, occur at Hanover, N. H.; and a clear and deep red variety, sometimes called *pyrope,* comes from Green's Creek, Delaware County, Penn. Dodecahedrons, of a *dark red color,* occur at Haverhill and Springfield, N. H., some 1½ inches through; also at New Fane, Vt., still larger; at Unity, Brunswick, Streaked Mountain, and elsewhere, Maine; at Monroe, Lyme and Redding, Conn.; Bedford, Chesterfield, Barre, Brookfield, and Brimfield, Mass.; Dover, Dutchess County, Roger's Rock, Crown Point, Essex County, N. Y.; Franklin, N. J. *Cinnamon-colored crystals* occur at Carlisle, Mass., transparent, and also at Boxborough; with idocrase at Parsonsfield, Phippsburg and Rumford, Me.; at Amherst, N. H.; at Amity, N. Y., and Franklin, N. J.; at Dixon's Quarry, seven miles from Wilmington, Del., in fine trapezohedral crystals. *Melanite* is found at Franklin, N. J., and Germantown, Penn. *Chrome garnet* is found in Orford, Canada. *Colophonite* is abundant at Willsborough and Lewis, Essex County, N. Y.: it occurs also at North Madison, Conn.

The garnet is the carbuncle of the ancients. The alabandic carbuncles of Pliny were so called because cut and polished at Alabanda, and hence the name *Almandine* now in use. The garnet is also supposed to have been the *hyacinth* of the ancients.

The clear deep-red garnets make a rich gem, and are much used. Those of Pegu are most highly valued. They are cut quite thin, on account of their depth of color. The cinnamon stone is also employed for the same purpose. Pulverized garnet is sometimes employed as a substitute for emery.

Pliny describes vessels, of the capacity of a pint, formed from large carbuncles, "devoid of lustre and transparency, and of a dingy color," which probably were large garnets.

Zircon.

Dimetric. $I \wedge I = 132°10'$; $1 \wedge 1 = 123°19'$. Cleavage parallel to I, but imperfect. Usually in crystals; but also granular.

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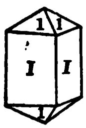

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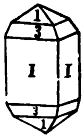

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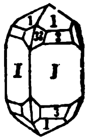

Color brownish red, brown, and red, of clear tints; also yellow, gray, and white. Streak uncolored. Lustre more or less adamantine. Often transparent; also nearly opaque. Fracture conchoidal, brilliant. H.=7·5. G.=4·0–4·8.

Composition. ZrO_4Si=Silica 33, zirconia 67=100. B.B. infusible, but loses color.

VARIETIES. Transparent red specimens are called *hyacinth.* A colorless variety from Ceylon, having a smoky tinge, is called *jargon;* it is sold for inferior diamonds, which it resembles, though much less hard. The name *zirconite* is sometimes applied to crystals of gray or brownish tints.

Diff. Zircon is readily distinguished from species which it resembles in other properties by its square prismatic form, specific gravity, and adamantine lustre.

Obs. The zircon is confined to crystalline rocks, occurring in granite, gneiss, granular limestone, and some igneous rocks. Zircon-syenyte is a syenyte with disseminated zircons. Zircon often occurs in auriferous sands. Hyacinth occurs mostly in grains in such sands, and comes from Ceylon, Auvergne, Bohemia, and elsewhere in Europe. Siberia affords crystals as large as walnuts. Splendid specimens come from Greenland.

In the United States, fine crystals of zircon occur in Buncombe County, N. C.; of a cinnamon-red color in Moriah, Essex County, N. Y.; also at Two Ponds and elsewhere, Orange County, in crystals sometimes an inch and a half long; in Hammond, St. Lawrence County, and Johnsbury, Warren County, N. Y.; at Franklin, N. J.; in Litchfield, Me.; Middlebury, Vt.; in Canada, at Grenville, etc.

The name *hyacinth* is from the Greek *huakinthos.* But it is doubtful whether it was applied by the ancients to stones of the zircon species.

The clear crystals (hyacinths) are of common use in jewelry. When heated in a crucible with lime, they lose their color, and resemble a pale straw-yellow diamond, for which they are substituted. Zircon is also used in jeweling watches. The hyacinth of commerce is to a great extent cinnamon stone, a variety of garnet. The earth zirconia is used as an advantageous substitute for lime in the oxyhydrogen lantern.

Auerbachite, Malacon, Tachyaphaltite, Œrstedite, Bragite, are names of zircon-like minerals supposed to be zircon partly altered.

The earth zirconia is also found in the rare minerals *eudialyte* and *wöhlerite;* also in *polymignite, æschynite;* also sparingly in *fergusonite.*

Vesuvianite.—Idocrase.

Dimetric. $O : 1 = 142^\circ\ 46'$; $1 \wedge 1 = 129^\circ\ 21'$, $1 : i\text{-}i = 127^\circ\ 14'$. Cleavage not very distinct parallel with *I*. Also found massive granular, and subcolumnar.

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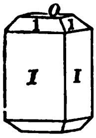

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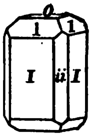

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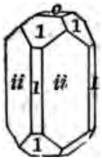


4.

Color brown; sometimes passing into green. In some varieties the color is oil-green in the direction of the axis and yellowish green at right angles with it. Streak uncolored. Lustre vitreous. Subtransparent to nearly opaque. H.=6·5. G.=3·33–3·4.

Composition. $(\frac{4}{7}Ca_3\,\frac{3}{7}\bar{A}l)_2\,O_{12}\,Si_3$. A small part of the Ca is usually replaced by magnesium, and part of the aluminum sometimes by iron in the sesquioxide state. Percentage of a common variety, Silica 37·3, alumina 16·1, iron sesquioxide 3·7, lime 35·4, magnesia 2·1, iron protoxide 2·9, water 2·1=99·6. B.B. fuses easily with effervescence to a greenish or brownish globule.

Diff. Resembles some brown varieties of garnet, tourmaline and epidote, but besides its difference of crystallization, it is much more fusible.

Obs. Vesuvianite was first found in the lavas of Vesuvius, and hence the name. It has since been obtained in Piedmont; near Christiania, Norway; in Siberia; also in the Fassa Valley. *Cyprine* includes blue crystals from Tellemarken, Norway; supposed to be colored by copper.

In the United States, it occurs in fine crystals at Phippsburg and Rumford, Sandford, Parsonsfield and Poland, Me.; Newton, N. J.; Amity, N. Y. In Canada at Calumet Falls, and at Grenville.

The name *idocrase* is from the Greek *eido,* to see, and *krasis,* mixture; because its crystalline forms have much resemblance to those of other species.

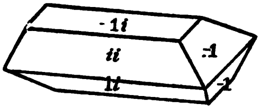
This mineral is sometimes cut as a gem for rings.

Mellilite in honey-yellow crystals (which includes *Hum-*

boldtilite) is a related dimetric species, from Capo di Bove, near Rome, and Mount Somma, Vesuvius.

Epidote.

Monoclinic. *i-i*∧1 *i*=115° 24′. *i-i*∧−1-*i*=116° 18′. −1∧−1=109° 35′. Cleavage parallel to *i-i*; less distinct parallel to 1-*i*. Also massive granular and forming rock masses; sometimes columnar or fibrous.



Color yellowish green (pistachio-green) and ash-gray or hair-brown. Streak uncolored. Translucent to opaque. Lustre vitreous, a little pearly on *i-i*; often brilliant on the faces of crystals. Brittle. H. =6–7. G.=3·25–3·5.

Composition. A lime iron-alumina silicate, the iron being mostly in the sesquioxide state and replacing aluminum. Percentage of common variety, Silica 37·83, alumina 22·63, iron sesquioxide 15·02, iron protoxide 0·93, lime 23·27, water 2·05=100·73.

B.B. epidote fuses with effervescence to a black glass which usually is magnetic. Partially decomposed by hydrochloric acid, but if first ignited, is then decomposed, and the solution gelatinizes on evaporation.

Green epidote is often called *Pistacite*. *Piedmontite* is a variety containing much manganese, of reddish-brown or reddish-black color.

Bucklandite is an iron-epidote.

Diff. The peculiar yellowish-green color of ordinary epidote distinguishes it at once. From zoisite and vesuvianite it differs in fusing to a black magnetic globule.

Obs. Occurs in crystalline rocks, especially in hornblendic rocks. It often occurs in the cavities of amygdaloidal rocks. Splendid crystals, six inches long, and with brilliant faces and rich color, have been obtained at Haddam, Ct. Crystallized specimens are also found at Franconia, N. H., Hadlyme, Chester, Newbury and Athol, Mass.; near Unity, Amity, and Monroe, N. Y.; Franklin and Warwick, N. J.; Pennsylvania, at E. Bradford; Michigan, in the Lake Superior region; Canada, at St. Joseph.

The name *epidote* was derived by Haüy from the Greek *epididomi*, to increase, in allusion to the fact that the base of the primary is frequently much enlarged in the crystals.

Zoisite. A mineral of the epidote group, occurring in trimetric crystals, with $I \wedge I = 116^\circ\ 40'$, and having a white, pale-grayish, pale-greenish to reddish color; also massive. H.=6–6·5. G.=3·1–3·4.

It is a lime-epidote, with little or no iron. B.B. swells up and fuses to a white blebby glass; after ignition, gelatinizes with hydrochloric acid. *Thulite* is a rose-red variety. Occurs at Saualpe in Carinthia, in the Tyrol; Arendal, etc.; in Vermont at Willsboro' and Montpelier; in Massachusetts, at Goshen, Chesterfield, etc.; in Pennsylvania at Unionville, and in Tennessee at the Ducktown copper mine.

Saussurite, from the euphotide of the Alps in the vicinity of Lake Geneva, approaches zoisite in composition, it affording Hunt Silica 43·59, alumina 27·72, iron sequioxide 2·61, magnesia 2·98, lime 19·71, water 0·35, soda 3·08=100·04. Color whitish, greenish gray, ash-gray; G.=3 226–3·385. H.=6·5–7. The saussurite of Orezza gave nearly the same composition in an analysis by Boulanger, and that of Schwartzwald in general the same, with more of magnesia and less of lime, in an analysis by Hütlin. The high specific gravity separates it from scapolite (wernerite) which it resembles in composition, and also from the feldspar group.

Jadeite, one of the kinds of pale-green stones used in China for ornaments, called *feitsui*, has the high specific gravity of zoisite, but it has nearly the composition of oligoclase, if the iron and magnesia be excluded; analysis by Damour affording Silica 59·17, alumina 22·58, iron protoxide 1·56, magnesia 1·15, lime 2·68, soda 12·93=100·07. It is the material of some of the ornaments in the Swiss lake-dwellings.

Allanite.—A cerium epidote, of a pinchbeck-brown to brownish-black and black color, submetallic to pitch-like and resinous in lustre, crystallizing in the monoclinic system, and with the angles nearly of epidote. H.=5·5–6. G.=3–4·2.

B.B. fuses easily and swells up to a dark, blebby magnetic glass. Most varieties gelatinize with hydrochloric acid, but not after ignition. Found in Norway, Sweden, Greenland, Scotland; at Snarum, near Dresden; in Massachusetts, at the Bolton quarry; in New York, at Moriah in Essex County, Monroe in Orange County; in New Jersey, at Franklin; in Pennsylvania, at East Bradford and Eaton; in Virginia, Amherst County; in Canada, at St. Paul's.

Orthite is a variety in long slender crystals. *Muromontite*, *Bodenite*, and *Michaelsonite* are related minerals.

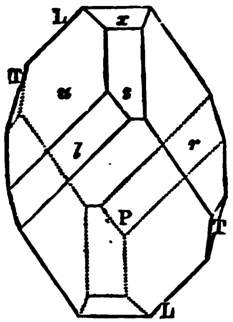
Gadolinite. A mineral of a greenish-black color, containing lithium, cerium, and barium, from Sweden, Greenland, and Norway. Crystals monoclinic, with $I \wedge I = 116^\circ$. H.=6·5–7. G.=4–4·5.

Mosandrite. Reddish-brown to dull greenish or yellowish-brown silicate of cerium, lanthanum and didymium, calcium, and titanium. H.=4. G.=2·9–3·03. From Brevig, Norway.

Ilvaite (*Yenite*). In trimetric striated prisms, of an iron-black to grayish-black color. $I \wedge I = 112^\circ\ 38'$. H.=5·5–6. G.=3·7–4·2. In composition a calcium-iron silicate in which part of the iron is in the sesquioxide state. From Elba; Fossum and Skeen in Norway, etc. Also reported as occurring at Cumberland, R. I., and Milk Row quarry, in Somerville, Mass. The name *Ilvaite* is derived from the Latin name of the Island of Elba.

Axinite.

Triclinic. In acute-edged oblique rhomboidal prisms; $P \wedge r = 134° 45'$, $r \wedge u = 115° 38'$, $P \wedge u = 135° 31'$. Cleavage indistinct. Also rarely massive or lamellar.



Color clove-brown; differing somewhat in shade in three directions, being trichroic. Lustre vitreous. Transparent to subtranslucent. Brittle. H. = 6·5–7. G. = 3·27. Pyro-electric.

Composition. A unisilicate, affording boron trioxide, and containing boron among its bases. One analysis afforded Silica 43·68, boron trioxide 5·61, alumina 15·63, iron sesquioxide 9·45, manganese sesquioxide 3·05, lime 20·92, magnesia 1·70, potash 0·64 = 100·43. B.B. fuses easily with intumescence to a dark-green or black glass, imparting a pale-green color to the flame, which is due to the boron.

Diff. Remarkable for the sharp thin edges of its crystals, and its glassy brilliant appearance, without cleavage. The crystals are implanted, and not disseminated like garnet. In one or all of these particulars, and also in blowpipe reaction, it differs from any of the titanium ores.

Obs. Occurs at St. Cristophe in Dauphiny; at Kongsberg in Norway; Normark in Sweden; Santa Maria, in Switzerland; Cornwall, England; Thum in Saxony, whence the name *Thummerstein* and *Thumite.*

In the United States it has been found at Phippsburg and Wales in Maine; and at Cold Spring, New York.

Danburite. A silicate which contains, like axinite, boron trioxide. *Composition:* Silica 48·8, boron trioxide 28·5, lime 22·7. Occurs with oligoclase and orthoclase in imbedded masses of a pale-yellow color, at Danbury, Conn. H. = 7. G. = 2·95–2·96.

Iolite.—Dichroite. Cordierite.

Trimetric. In rhombic prisms of 120°, and in 6 and 12-sided prisms. Also massive. Cleavage indistinct; but crystals often separable into layers parallel to the base, especially after partial alteration.

Color various shades of blue, looking often like a pale or dark blue glass; often deep blue in direction of the axis, and yellowish gray transversely. Streak uncolored. Lustre vitreous. Transparent to translucent. Brittle. H.=7–7·5. G.=2·6–2·7.

Composition. A silicate of aluminum, magnesium and iron, corresponding to Silica 49·4, alumina 33·9, magnesia 8·8, iron protoxide 7·9=100. B.B. loses its transparency and with much difficulty fuses.

Diff. The glassy appearance of iolite is so peculiar that it can be confounded with nothing but blue quartz, from which it is distinguished by its fusing on the edges. It is easily scratched by sapphire.

Obs. Found at Haddam, Conn., in granite; also in gneiss at Brimfield, Mass.; at Richmond, N. H., in talcose rock. The principal foreign localities are at Bodenmais in Bavaria; Arendal, Norway; Capo de Gata, Spain; Tunaberg, Finland; also Norway, Greenland and Ceylon.

The name iolite is from the Greek *ion,* violet, alluding to its color; it is also called *dichroite,* from *dis,* twice, and *chroa,* color, owing to its having different colors in two directions.

Occasionally employed as an ornamental stone, and is cut so as to present different shades of color in different directions.

Iolite exposed to the air and moisture undergoes a gradual alteration, becoming hydrous, and assuming a foliated micaceous structure, so as to resemble talc, though more brittle and hardly greasy in feel. *Hydrous Iolite, Fahlunite, Chlorophyllite,* and *Esmarkite,* are names that have been given to the altered iolite; and *Gigantolite* and a number of other like minerals are of the same origin. (See p. 315.)

MICA GROUP.

The minerals of the mica group are alike in having (1) their crystals monoclinic; (2) the front plane angle of the base, or of the cleavage laminæ, 120°; (3) cleavage eminent, parallel to the base, affording very thin laminæ; and (4) aluminum and potassium among the essential constituents. The combining or quantivalent ratio for the bases and silicon is usually 1 to 1 in Biotite, Phlogopite, and Lepidomelane; 1 to more than 1 in Muscovite, Lepidolite, etc.

The ordinary light-colored micas are mostly Muscovite, and the black, mostly Biotite. Lepidolite is a light-colored mica containing lithia; and Lepidomelane a black mica containing more iron than biotite. Muscovite and biotite are so closely related that crystals of the latter often occur that are finished out uninterruptedly by muscovite, the axial lines of the one continuous with those of the other; and such crystals are sometimes several inches across. There is here a compound structure chemically, but no twinning in the crystallization. When a thin plate of mica is struck with a pointed awl or other tool a symmetrical star of six rays is produced, the rays being cleavage lines parallel to the sides of the rhombic prism *I* and the shorter diagonal.

Biotite.

Monoclinic. Crystals usually short erect rhombic or hexagonal prisms. Common in disseminated scales; also in masses made up of an aggregation of scales.

Color dark green to black, rarely white. Transparent to opaque. Lustre more or less pearly on a cleavage surface. Optic-axial angle usually less than 1°; crystals appear often to be uniaxial. H.=2·5–3. G.=2·7–3·1.

Composition. Mostly $(K_2,Mg,Fe)_3Al\,O_{12}Si_6$, a variety afforded Silica 40·91, alumina 17·79, iron oxides 10·00, magnesia 19·04, potash 9·96. B.B. whitens and fuses on thin edges; sometimes the flame is red owing to the presence of a little lithium.

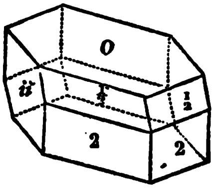
Lepidomelane. Like biotite, but containing more iron oxides and less of magnesia than biotite, and folia brittle. Fuses easily to a black magnetic globule. *Annite* (from Cape Ann, Mass.) is near Lepidomelane.

Phlogopite. Contains much magnesia and little or no iron. Color yellowish brown to brownish red, somewhat copper-like in its reflections; also white or colorless. Optic-axial angle 3° to 20°. H.=2·5–3. G.=2·78–2·85. In crystals and scales in granular limestone From Gouverneur, Edwards, and other places in Northern New York; Stirling Mine, and Newton, N. J.; St. Jerome, and Burgess, Canada; in the Vosges. *Aspidolite*, from the Tyrol, is a related mica.

Astrophyllite. A bronze-yellow mica affording nearly 8 per cent. of titanium dioxide. From Brevig, Norway, and El Paso County, Colorado.

Muscovite.—Common Mica.

Monoclinic. In oblique rhombic prisms of about 120°. Crystals commonly have the acute edge replaced, as in the accompanying figure (plane *i-i*). Usually in plates or scales. Sometimes in radiated groups of aggregated scales or small folia.



Colors from white through green, yellowish and brownish shades; rarely rose-red. Lustre more or less pearly. Transparent or translucent. Tough and elastic. H.=2–2·5. G.=2·7–3. Optic-axial angle 44° to 78°.

Composition. A common variety afforded Silica 46·3, alumina 36·8, potash 9·2, iron sesquioxide 4·5, fluoric acid 0·7, water 1·8=99·3. Often contains 3 to 5 per cent. of water, and thus passes to a hydrous mica called *Margarodite.* (See page 313). B.B. whitens and fuses on the thinnest edges, but with great difficulty, to a gray or yellow glass.

A variety in which the scales are arranged in a plumose form is called *plumose mica;* another, in which the plates have a transverse cleavage, has been termed *prismatic mica.*

Diff. Differs from talc and gypsum in affording thinner and much tougher folia, and in being elastic; but muscovite when hydrous loses its elasticity, and becomes more pearly in lustre.

Obs. Muscovite is a constituent of granite, gneiss and mica schist, and gives to the latter its schistose structure. It also occurs in granular limestone. Plates two and three feet in diameter, and perfectly transparent, have been obtained at Alstead, and Grafton, New Hampshire, and it has been mined at these places, and in Orange and elsewhere. Other good localities are Paris, Me.; Chesterfield, Barre, Brimfield, and South Royalston, Mass.; near Greenwood Furnace, Warwick and Edenville, Orange County, and in Jefferson and St. Lawrence counties, N. Y.; Newton and Franklin, N. J.; near Germantown, Pa.; Jones's Falls, Maryland. Oblique prisms from near Greenwood are sometimes six or seven inches in diameter. Western North Carolina affords much mica for commerce.

A green variety occurs at Unity, Maine, near Baltimore, Md., and at Chestnut Hill, Pa. Prismatic mica is found at Russel, Mass.

On account of the toughness, transparency, and the thinness of its folia, mica was formerly used in Siberia for glass in windows, whence it has been called *Muscovy glass.* It is in common use for lanterns, and also for the doors of stoves, and other purposes which demand a transparent substance not affected by heat.

Lepidolite, or *Lithia mica.* Resembles muscovite. Color rose-red, and lilac to white; in crystalline plates and aggregations of scales. It contains from 2 to 5 per cent. of lithia, and hence B.B. imparts a deep crimson color to the flame.

From Rozena in Moravia; Zinnwald in Bohemia (the *Zinnwaldite*); Saxony; the Ural; Sweden; Cornwall; Paris, and Hebron, Maine; Chesterfield, Mass.; Middletown, Conn. The red mica of Goshen is muscovite.

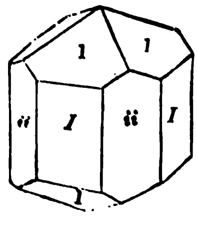
Cryophyllite has the same constituents as lepidolite. It fuses easily in the flame of a candle. From Cape Ann, Mass.

SCAPOLITE GROUP.

The Scapolite species are dimetric in crystallization, usually white in color or of some light shade, and analyses afford alumina and lime with or without soda. The lime scapolites are unisilicate in ratio; the others, containing alkali, have, with one exception, more silica than this ratio requires.

Wernerite.—Scapolite

Dimetric. 1 : 1=136° 7′. Cleavage rather indistinct parallel with *i-i* and *I*. Also massive, sublamellar, or sometimes faintly fibrous in appearance.



Colors light; white, gray, pale blue, greenish or reddish. Streak uncolored. Transparent to nearly opaque. Lustre usually a little pearly. H.=5–6. G.=2·6–2·8.

Composition. $(\frac{1}{3}(Ca,Na_2)\frac{2}{3}\overline{Al})_2O_{12}Si_3$= Silica 48·4, alumina 28·5, lime 18·1, soda 5·0=100. B.B. fuses easily with intumescence to a white glass. Imperfectly decomposed by hydrochloric acid.

Diff. Its square prisms and the angle of the pyramid at summit are characteristic. In cleavable masses it resembles *feldspar,* but there is a slight fibrous appearance often distinguished on the cleavage surface of scapolite, which is peculiar. It is more fusible than feldspar, and has higher specific gravity. *Spodumene* has a much higher specific gravity, and differs in its action before the blowpipe. *Tabular spar* is more fibrous in the appearance of the surface, and is less hard; it also gelatinizes with acids.

Obs. Found mostly in the older crystalline rocks, and also in some volcanic rocks. It is especially common in granular limestone. Fine crystals occur at Gouverneur, N. Y., and at Two Ponds and Amity, N. Y.; at Bolton, Boxborough and Littleton, Mass.; at Franklin and Newton, N. J. It occurs massive at Marlboro', Vt.; Westfield, Mass.; Monroe, Ct. Foreign localities are at Arendal, Norway; Wärmland, Sweden; Pagas in Finland, and also at Vesuvius, whence come the small crystals called *meionite.*

Nuttallite, Glaucolite, are varieties of this species.

Ekebergite resembles wernerite, being distinguishable from it only by chemical analysis. *Dipyre* also is near wernerite, but contains more silica and 10 per cent. of soda; from the Pyrenees.

Meionite, a lime scapolite, is like wernerite in its crystals, but has the formula $(\frac{1}{3}Ca\frac{2}{3}Al)_2 O_{12} Si_3$, being a true unisilicate. From Monte Somma.

Mizzonite and *Marialite* resemble meionite. *Paranthine* and *Sarcolite* are other related unisilicate species.

Nephelite.—Nepheline.

Hexagonal. In hexagonal prisms with replaced basal edges; $O \wedge 1 = 135° 55'$. Also massive; sometimes thin columnar.

Color white, or gray, yellowish, greenish, bluish-red. Lustre vitreous or greasy. Transparent to opaque. H.= 5·5–6. G.=2·5–2·65.

Composition. $(Na_2, K_2)Al\,O_8\,Si_2$= (if Na : K=5 : 1) Silica 44·2, alumina 33·7, soda 16·9, potash 5·2=100; a little lime is usually present. B.B. fuses quietly to a colorless glass. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation. The name *nephelite* alludes to the mineral becoming clouded in acid. Nephelite includes the glassy crystals from Vesuvius called *Sommite,* and also hexagonal crystals in other volcanic rocks; and a massive variety, of greasy lustre, called *Elæolite,* from the Greek *elaion*, oil. Altered crystals are in part the mineral *Gieseckite.*

Diff. Distinguished from scapolite and feldspar by the greasy lustre when massive, and its forming a jelly with acids; from apatite by the last character, and also its hardness.

Obs. Nephelite is the prominent constituent of nephelin-doleryte or nephelinyte, and phonolyte, and occurs also in some other eruptive rocks; and it also enters into the constitution of miascyte, zircon-syenyte, metamorphic rocks. Among the localities are Vesuvius and C. di Bove, in Italy; Katzenbuckel, near Heidelberg; Aussig in Bohemia; and as elæolite, Brevig, Norway; in Siberia; in the Ozark Mountains, Arkansas; in Litchfield, Maine.

Cancrinite. Crystals like those of nephelite, and composition similar, except the presence of some carbonates and usually water. Color white, gray, yellow, green, blue, or reddish; H. = 5–6. G. = 2·4–2·5. On account of the carbonates it effervesces in acids. B.B. fuses very easily.

Occurs in crystalline rocks at Miask in the Ural; in Norway; Transylvania; and at Litchfield in Maine, with elæolite and sodalite. Supposed to be altered nephelite.

Microsommite is near. Sommite (nephelite).

Sodalite.

Isometric. In dodecahedrons; cleavage dodecahedral. Color brown, gray, or blue. H. = 6. G. = 2·25–2·3.

Composition. $Na_2\,Al\,O_8\,Si_2 + \frac{1}{2}\,Na\,Cl$ = Silica 37·1, alumina 31·7, soda 19·2, sodium 4·7, chlorine 7·3 = 100. B.B. fuses with intumescence to a colorless glass. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

Occurs in eruptive and metamorphic rocks. Found in Sicily; near Lake Laach; at Miask; in Norway; West Greenland; of a blue color at Litchfield, Me.; and lavender-blue at Salem, Mass.

Haüynite (or Hauyne) and ***Nosite*** (or Nosean) are related minerals from lavas or other eruptive rocks; and ***Ittnerite*** is altered haüynite or nosite. Isometric. In dodecahedrons. Color bright blue, occasionally greenish. Transparent to translucent. H. = 6. G. = 2·4–2·5.

Lapis-Lazuli.—Ultramarine.

Isometric. In dodecahedrons; cleavage imperfect. Usually massive. Color rich Berlin or azure blue. Lustre vitreous. Translucent to opaque. H. = 5·5. G. = 2·3–2·5.

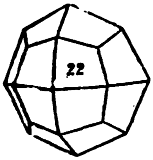
Composition. Silica 45·5, alumina 31·8, soda 9·1, lime 3·5, iron 0·8, sulphuric acid 5·9, sulphur 0·9, chlorine 0·4, water 0·1=98·0. B.B. fuses to a white translucent or opaque glass, and if calcined and reduced to powder loses its color in acids; is decomposed with the evolution of hydrogen sulphide, and the solution gelatinizes on evaporation. The color of the mineral is supposed to be due to sodium sulphide. The mineral is not homogeneous, but the exact nature of the ultramarine species at the basis of it is not yet ascertained.

Obs. Found in syenyte and granular limestone, and is brought from Persia, China, Siberia, and Bucharia. The specimens often contain scales of mica and disseminated pyrites.

The richly-colored lapis-lazuli is highly esteemed for costly vases, and for inlaid work in ornamental furniture. It is also used in the manufacture of mosaics. When powdered it constitutes a beautiful and durable blue paint, called *Ultramarine,* which has been a costly color. The discovery of a mode of making an artificial ultramarine, quite equal to the native, has afforded a substitute at a comparatively cheap rate. This artificial ultramarine consists of silica 45·6, alumina 23·3, soda 21·5, potash 1·7, lime *trace,* sulphuric acid 3·8, sulphur 1·7, iron 1·1, and chlorine a small quantity undetermined. It has taken the place in the arts, entirely, of the native lapis-lazuli.

Leucite.—Amphigene.

Dimetric. Form very nearly that of the trapezohedron represented in the figure. Cleavage imperfect. Usually in dull glassy crystals, of a grayish color; sometimes opaque-white, disseminated through lava. Translucent to opaque. H.=5·5–6. G.=2·5. Brittle.



Composition. $K_2\,Al\,O_{12}\,Si_4$ = Silica 55·0, alumina 23·5, potash 21·5=100. B.B. infusible. Moistened with cobalt nitrate and ignited assumes a blue color. Decomposed by hydrochloric acid, without gelatinizing.

Diff. Distinguished from analcite by its hardness and infusibility.

Obs. In volcanic rocks, and abundant in those of Italy, especially at Vesuvius, where crystals occur from the size of a pin's head to a diameter of an inch. Also found in the Leucite Hills, northwest of Point of Rocks, Wyoming Territory.

The name leucite is from the Greek *leukos*, white.

FELDSPAR GROUP.

I. Relations of the Species of Feldspar.

The species of the Feldspar Group are related—

A. In crystallization: (1) the forms being all oblique; (2) the angle of the fundamental rhombic prism *I*, in each, nearly 120°; (3) the other angles differing but little, although part of the species are monoclinic and part triclinic; and (4) there being two directions of easy cleavage, one, the most perfect, parallel to the basal plane *O*, and the other parallel to the shorter diagonal section, with the intervening angle either 90° (as in the monoclinic species orthoclase and hyalophane), or nearly 90° (as in the triclinic species).

B. In composition: (1) the only element in the sesquioxide state being aluminum, and those in the protoxide state either calcium, barium, sodium, or potassium, or two or three of these bases together; (2) the ratio of 1 atom of R to 1 of $\bar{\text{R}}$ being constant; (3) the amount of silica in the species increasing with the proportion of alkali, being that of a unisilicate in the pure lime-feldspar, anorthite, that of a tersilicate in the soda-feldspar, albite, or potash-feldspar, orthoclase, and so directly proportioned to the alkali, that the amount in any lime-and-soda feldspar may be deduced by taking the lime (or calcium) as existing in the state of a unisilicate, and the soda in that of a tersilicate, and adding the two together.

Anorthite has the formula $\text{Ca}\bar{\text{Al}}\,\text{O}_8\,\text{Si}_2$.
Albite " " $\text{Na}_2\bar{\text{Al}}\,\text{O}_{16}\,\text{Si}_6$.

The constitution of a species containing Ca and Na_2 in the ratio of 1 to 1 for the protoxide portion may be obtained as follows. Adding together the anorthite and albite formulas, we have $\mathrm{CaNa_2\bar{Al}_2\,O_{24}\,Si_8}$; then dividing by 2, the formulas becomes $\mathrm{\frac{1}{2}Ca\frac{1}{2}Na_2\bar{Al}\,O_{12}\,Si_4}$, which expresses the composition of andesite. With 3 parts of the Ca unisilicate, and 1 of the $\mathrm{Na_2}$ tersilicate, the composition is that of labradorite. So it is for other combinations, that is for other species between anorthite and albite in composition.

The quantivalent ratio for the R, Al, Si, in the several species of the group, is as follows: V means *triclinic* in crystallization, and IV *monoclinic*.

	RATIO.	SYSTEM OF CRYSTALLIZATION.		RATIO.	SYSTEM OF CRYSTALLIZATION.
Anorthite,	1 : 3 : 4	V,	Oligoclase,	1 : 3 : 9	V.
Labradorite,	1 : 3 : 6	V,	Albite,	1 : 3 : 12	V.
Hyalophane,	1 : 3 : 8	IV,	Microcline,	1 : 3 : 12	V.
Andesite,	1 : 3 : 8	V,	Orthoclase,	1 : 3 : 12	IV.

These are the *normal* ratios; but there is some variation from them in the analyses, part of which is variation in actual composition, and part a result of interlamination or mixture of two feldspars together. Thus, orthoclase occurs mixed with microcline, albite, or oligoclase. But while such mixtures account for the soda found in some analyses of orthoclase, it does not for that in all, since soda does occur in many specimens of pure orthoclase, replacing part of the potash. It is the same with the triclinic feldspar microcline, which has the composition of orthoclase, and may have the alkali portion all potash or part soda, one analysis of typical microcline giving only 0·48 of soda. It is, hence, not safe to calculate the percentage of orthoclase present in a feldspar from the percentage of potash. Moreover, potash is present in much albite.

The above ratios show that anorthite has for the ratio between $\mathrm{R}+\bar{\mathrm{R}}$ and Si, 4 : 4, or 1 : 1, as in true unisilicates; while in albite and orthoclase, the same ratio is 4 : 12 or 1 : 3, that of a tersilicate, as above stated.

C. In physical characters: the hardness being between 6 and 7; the specific gravity, between 2·44 and 2·75; lustre vitreous, but often pearly on the face of perfect cleavage; and each species transparent to subtranslucent.

II. ACIDIC AND BASIC FELDSPARS.

Oligoclase, albite, and orthoclase are called *acidic* feldspars, because of the large amount of the acidic element, silicon, in their constitution, analyses giving 60 to 70 per cent. of silica; and labradorite and anorthite are called basic feldspars, the amount of silica being 42 to 55 per cent. Correspondingly, eruptive, and metamorphic rocks in which either of the acidic feldspars is a prominent constituent—for example, granite, gneiss, trachyte, true porphyry—are called acidic rocks; while those rocks in which basic feldspars are constituents—like doleryte, and a large part of eruptive rocks—are called basic rocks.

III. DISTINCTIONS OF THE TRICLINIC FELDSPARS.

The triclinic feldspars are distinguished from the monoclinic (*e. g.* orthoclase) by the occurrence of very fine striations on the cleavage surface, sometimes too fine to be seen without a good pocket-lens. These striations are due to multiple twinning parallel to the other cleavage face, as explained on page 57. They are rarely absent from triclinic feldspar crystals. They are best brought out by transmitted polarized light, in which a transverse section of the crystal is seen banded with spectrum colors, each band corresponding to one plate of the twin structure.

The triclinic feldspars, andesite excepted, may be distinguished from one another by an optical method when the cleavage direction can be made out. For this purpose a plate is prepared parallel to the plane of easiest cleavage. In such a plate the multiple twinning is parallel to the other cleavage plane, or the shorter diagonal. When the plate is placed on the stage of a polariscope, between crossed Nicol-prisms, as the stage is revolved, the adjoining bands of color become dark alternately, and the angle through which the plate has to be revolved for the change between consecutive bands varies for different species, it being 54° to 74° for anorthite, 10° to 14° for labradorite, 4° to 8° for oligoclase, 6½° to 8° for albite, and 30° for microcline. The shorter diagonal of the crystal bisects this angle, so that the angle made with this diagonal is 27° to 37° for anorthite, 5° to 7° for labradorite, 2° to 4° for oligoclase, 3½° to 4° for albite, and 15° for microcline. Obtaining cleavage plates for such measurements in the case of slices for microscope investigation, is seldom possible, and when not so, the only certain resource for the distinguishing of triclinic feldspars is chemical analysis. These feldspars have been called *plagioclase* (from the Greek words for *oblique* and *fracture*), as if all were of one species. The term is a convenient cover for ignorance.

IV. DISTINCTIONS FROM OTHER MINERALS. When in crystals, the form is sufficient to determine a feldspar; so also the fact of two unequal cleavages inclined to one another at 84° to 90°, one of them quite perfect. No fibrous, columnar, or micaceous varieties are known. They differ from rhodonite, by the absence of a manganese reaction; from spodumene, by the absence of a lithia reaction as well as cleavage angles; from scapolite, by form, the cleavage angles, the more difficult fusibility; from nephelite, by form, and also in difficult fusibility, and not gelatinizing with acids, except in the case of anorthite and labradorite, which fuse with but little more difficulty than nephelite, and often will gelatinize.

Anorthite.—Indianite. Lime Feldspar.

Triclinic. Angle between the two cleavage planes 85° 50' and 94° 10'. Crystals tabular. Also massive granular or coarse lamellar. Color white, grayish, or reddish.

Composition. $\mathrm{CaAl\,O_8\,Si_2}$=Silica 43·1, alumina 36·8, lime 20·1=100. B.B. fuses with much difficulty to a colorless glass; decomposed by hydrochloric acid, the solution gelatinizes on evaporation.

Obs. Occurs in basic eruptive rocks; also in some metamorphic rocks. Found in the lava of Vesuvius; in the Tyrol; Faroe Islands, Iceland; in imbedded crystals in some doleryte of the Connecticut Valley.

At Hanover, N. H., anorthite crystals occur altered to a silicate which afforded, in an analysis by Hawes, only 2·2 of lime, and, in place of the rest of this ingredient, 7·11 of potash, 3·77 of soda, 1·10 of iron-sesquioxide, and 2·67 of water, with 30·05 of alumina and 52·52 of silica; which compound, if the water be made basic, has the ratio nearly of labradorite, though distinct from that species in the alkalies, and also in specific gravity, which is 2·96 or very nearly 3. It has some relation to zoisite, and to typical saussurite, but is widely different in constituents and ratio; it is related also to jadeite. (See page 263.)

Labradorite.—Lime-soda Feldspar. Labrador Feldspar.

Triclinic. Angle between the cleavage planes 93° 20′ and 86° 40′. Usually in cleavable massive forms.

Color dark gray, brown, or greenish brown; also white or colorless. Often a series of bright chatoyant colors from internal reflections, especially blue and green, with more or less of yellow, red, and pearl-gray.

Composition. $\frac{3}{4}Ca\frac{1}{4}Na_2Al\,O_{10}\,Si_3$ = Silica 52·9, alumina 30·3, lime 12·3, soda 4·5 = 100. Sometimes contains a little potash in place of the soda. B.B. fuses quite easily to a colorless glass. Only partially decomposed by hydrochloric acid.

Obs. A constituent of the larger part of eruptive rocks, as doleryte, and amphigenyte, and many lavas; and also of some metamorphic rocks. Occurs as an ingredient in part of the Archæan rocks in North America, and was named from its first discovery in Labrador.

Andesite. Triclinic. Angle between the cleavage planes 87°–88°. Near labradorite in composition. The formula $\frac{1}{2}Ca\,\frac{1}{2}Na_2\,Al\,O_{12}\,Si_4$ = Silica 59·8, alumina 25 5, lime 7·0, soda 7·7 = 100·0.

Hyalophane. Monoclinic, and hence angle between the cleavage planes 90°. A baryta feldspar; the formula like that of andesite, excepting the substitution of Ba for Ca and K_2 for Na_2. It has been found in the Binnenthal, Switzerland, and at Jakobsberg, Sweden.

A baryta-feldspar, having the ratio of andesite, 1 : 3 : 8, has been described which is *triclinic*, and approaches oligoclase in optical characters.

Oligoclase.—Soda-lime Feldspar.

Triclinic. Angle between the cleavage planes 93° 50′ and 86° 10′. Commonly in cleavable masses. Also massive.

Color usually white, grayish white, grayish green, greenish, reddish. Transparent, subtranslucent. H. = 6·7. G. = 2·5–2·7.

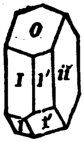
Composition. $\frac{1}{4}$Ca$\frac{3}{4}$Na$_2$Al O$_{14}$ Si$_8$=Silica 61·9, alumina 24·1, lime 5·2, soda 8·8=100. A portion of the soda is usually replaced by potash. B.B. fuses without difficulty; not decomposed by acids.

Obs. It occurs in granite, syenyte, and various metamorphic rocks, especially those containing much silica; and in such case usually associated with orthoclase. *Sunstone* is in part oligoclase containing disseminated scales of hematite giving bright reflection from the interior of the stone. Occurs in Norway. *Moonstone* is in part a whitish opalescent variety. Oligoclase occurs at Unionville, Pa.; Haddam, Conn.; Mineral Hill, Del.; Chester, Mass., etc.

Albite.

Triclinic. Angle between the cleavage planes 93° 36′, and 83° 24′. Figures 1 to 6 represent some of its forms;

1.



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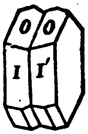

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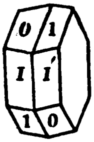

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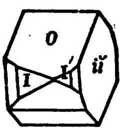

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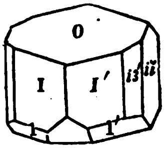

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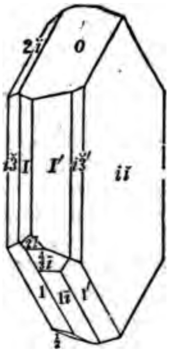

2 and 3 are twin crystals. The crystals are usually more or less thick and tabular. Also massive, with a granular or lamellar structure. Color white; occasionally light tints of bluish white, grayish, reddish and greenish. Transparent to subtranslucent.

Composition. Na$_2$Al O$_{16}$ Si$_6$=Silica 68·6, alumina 19·6, soda 11·8=100·0. B.B. fuses to a colorless or white glass, imparting an intense yellow to the flame. Not acted upon by acids.

usually white [illegible]

4 [illegible]

Cleavelandite is a lamellar variety occurring in wedge-shaped masses at the Chesterfield albite vein, Mass.

Obs. Albite occurs in some granites and gneiss, and is most abundant in granite veins. Fine crystals occur at Middletown and Haddam, Conn., at Goshen, Mass., and Granville, N. Y.; Unionville, Delaware County, Penn.

The name albite is from the Latin *albus*, white.

Microcline.

A *potash*-feldspar, very close to the following species in angles, and also in physical characters, and identical with it in composition. But it is very slightly triclinic, the angle between its cleavage planes varying but 16′ from 90°; and hence its cleavage surface shows usually the fine striations exhibited with rare exceptions by all the triclinic feldspars. Colors white, flesh-red, copper-green. The last is what has been called Amazon-stone; as heat destroys the color it has been supposed to be of organic origin.

Occurs in the zircon-syenyte of Norway; also in the Urals; Greenland; Labrador; Leverett, Mass.; Redding, Conn.; Delaware; Chester County, Penn.; White Mountain Notch, green; Pike's Peak, Amazon-stone; Magnet Cove, Ark.

Orthoclase.—Common Feldspar.

Monoclinic; and hence angle between the cleavage planes 90°. Figures 1 to 4 represent common forms, and 5 to 8 twin crystals. Usually in thick prisms, often rectangular, and also in modified tables. Also massive, with a granular structure, or coarse lamellar; also fine-grained almost flint-like in compactness. Colors light; white, gray, and flesh-red common; also greenish and bluish-white and green.

Composition. $K_2 Al O_{16} Si_6$ = Silica 64·7, alumina 18·4, potash 16·9=100. Soda sometimes replaces a portion of the potash. B.B. fuses with difficulty; not acted on by acids.

Common feldspar includes the common subtranslucent varieties; *Adularia*, the white or colorless subtransparent specimens, a name derived from Adula, one of the highest peaks of St. Gothard. *Sanidin* or *glassy feldspar* includes transparent vitreous crystals, found in trachytes and lavas; but some of the "glassy feldspar" belongs to the species anorthite. *Loxoclase* is a grayish variety with a pearly or greasy lustre that contains much soda.

Moonstone is an opalescent variety of adularia, having when polished peculiar pearly reflections. *Sunstone* is similar; but contains minute scales of mica. *Aventurine feldspar* often owes its iridescence to minute crystals of specular or titanic iron, or limonite. *Sunstone* and *moonstone* are mostly oligoclase, and so is a large part of aventurine feldspar.

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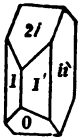

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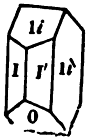

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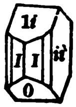

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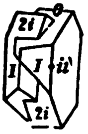

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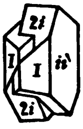

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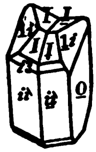

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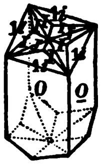

Diff. Distinguished from the other feldspars by its right-angled cleavage and the absence of striated surfaces.

Obs. Orthoclase is one of the constituents of granite, syenyte, gneiss, and other related rocks; also of porphyry, and trachyte; and it often occurs in these rocks in imbedded crystals. St. Lawrence County, N. Y., affords fine crystals; also Orange County, N. Y.; Haddam and Middletown, Conn.; Acworth, N. H.; South Royalston and Barre, Mass., besides numerous other localities. Green feldspar occurs at Mount Desert, Me.; an aventurine feldspar at Leiperville, Penn.; adularia at Haddam and Norwich, Conn., and Parsonsfield, Me. A fetid feldspar (sometimes called *necronite*) is found at Roger's Rock, Essex County; at Thomson's quarry, near 196th Street, New York City, and 21 miles from Baltimore. Carlsbad and Elbogen in Bohemia, Baveno in Piedmont, St. Gothard, Arendal in Norway, Land's End, and the Mourne Mountains, Ireland, are some of the more interesting foreign localities.

Felsite is compact, uncleavable orthoclase, having the texture of jasper or flint, which it much resembles. It often contains some disseminated silica. It occurs of various colors, as white, gray, brown, red, brownish red and black, and is sometimes banded. It is distinguished from flint or jasper by its fusibility.

Felsite is the material of beds or strata in some rock formations, and also of dikes or masses of eruptive rocks. It is the base of much red porphyry. The vicinity of Marblehead, Mass., is one of its localities.

The name feldspar is from the German word *Feld,* meaning *field.* It is, therefore, wrong to write it *felspar.*

Orthoclase is used extensively in the manufacture of porcelain. The large granite veins of Middletown and Portland, Conn., are quarried in several places for both orthoclase and quartz for this purpose; the places are often called China-stone quarries.

Kaolin. This name is applied to the clay that results from the decomposition of feldspar. See *Kaolinite,* p. 310.

III. SUBSILICATES.

In the Subsilicates, as stated on page 242, the combining or quantivalent ratio between the bases and silica is 1 to less than 1. In Chondrodite, the first of the following species, the ratio is 4 : 3; in Tourmaline, Andalusite, Cyanite, and Fibrolite, 3 : 2. Analyses of Andalusite obtain 1 of alumina, $Al\,O_3$, to 1 of silica, $Si\,O_2$, giving the oxygen ratio for bases and silica 3 : 2. This is the composition also of cyanite and fibrolite; so that the three species, andalusite, cyanite, and fibrolite are the same in constituents and atomic ratio while differing in crystalline form, exemplifying a case of *trimorphism* among minerals.

The ratio 3 : 2 exists also in Topaz, Euclase and Datolite in Titanite or sphene, and in Keilhauite. In Staurolite, the ratio was formerly regarded as 2 : 1; but the most recent analyses, those of Rammelsberg, give 11 : 6, or $1\frac{5}{6}$: 1. In datolite and tourmaline the basic constituents include boron; in titanite and keilhauite, titanium; in datolite, euclase, and part of staurolite, hydrogen, that is, the hydrogen of the water found on analysis. In chondrodite, topaz, and some tourmaline, fluorine replaces part of the oxygen.

Chondrodite.—Humite in part (Scacchi's Type II).

Monoclinic. Cleavage indistinct. Usually in imbedded grains or masses. Color light yellow to brownish yellow, yellowish red, and garnet-red. Lustre vitreous, inclining a little to resinous. Streak white, or slightly yellowish or grayish. Translucent or subtranslucent. Fracture uneven. H.=6–6·5. G.=3·1–3·25.

Composition. $Mg_8 O_{14} Si_3$; but a portion of the magnesium replaced by iron, and a part of the oxygen by fluorine. A specimen from Brewster's, New York, afforded Silica 34·1, magnesia 53·7, iron protoxide 7·3, fluorine 4·2, with 0·48 of alumina=99·72.

B.B. infusible. Decomposed by hydrochloric acid; the solution gelatinizes on evaporation.

Diff. As it occurs only in limestone it will hardly be confounded with any species resembling it in color when the gangue is present. It does not fuse like tourmaline or garnet, some brownish-yellow varieties of which it approaches in appearance. The name is from the Greek *chondros,* a grain.

Obs. It is abundant in the adjoining counties, Sussex, N. J., and Orange, N. Y., occurring at Sparta and Bryam, N. J., and in Warwick and other places in N. Y.; at the Tilly Foster Iron Mine, Brewster's, Putnam County, N. Y., it is very abundant. At Vesuvius it occurs in small crystals.

The species was early named *Chondrodite,* from Finland specimens; soon afterward small crystals, found in the lavas of Somma (Vesuvius), were named *Humite,* and both were referred to the same species. It has recently been ascertained that under this species, two species of different angles and form, but related composition and physical character, are included. For these species the names Humite and Clinohumite have been adopted.

Humite is orthorhombic, and embraces part of the Humite crystals of Vesuvius (Scacchi's Type I.), and some large coarse chondrodite-like crystals found at Brewster's, N. Y.

Clinohumite is monoclinic, and includes Scacchi's Type III.

of Humite from Vesuvius, and fine chondrodite-like crystals from Brewster's.

Tourmaline.

Rhombohedral. Usual in prisms of 3, 6, 9, or 12 sides, terminating in a low 3-sided pyramid. The sides of the prisms are often rounded and striated. Other forms are shown in the figures. The common pyramid is the rhombohedron $-\frac{1}{2}$ in the figures, the angle of which is 133° 8′. The crystals often have unlike secondary planes at the two extremities, as shown in figure 3. Occurs also compact massive, and coarse columnar, the columns sometimes radiating or divergent from a centre.

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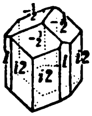

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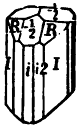

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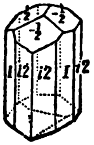

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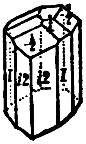

Color black, blue-black, and dark brown, common; also bright and pale red, grass-green, cinnamon-brown, yellow, gray, and white. Sometimes red within and green externally, or one color at one extremity and another at the other. Transparent; usually translucent to nearly opaque. Dichroic. Lustre vitreous, inclining to resinous on a surface of fracture. Streak uncolored. Brittle; the crystals often fractured across and breaking very easily. H.=7·0–7·5. G.=3–3·3.

Composition. $(\dot{R}_3, B_2, \bar{R}_2) O_5, Si_2$, in which $\dot{R}$ includes, in different varieties, Fe, Mg, Na_2, with often traces also of Ca, Mn, K_2, Li_2; $\bar{R}$ includes aluminum, with some boron in the trioxide state replacing Al; and a little of the oxygen is sometimes replaced by fluorine.

A black tourmaline from Haddam afforded on analysis, Silica 37·50, boron trioxide (by loss) 9·02, alumina 30·87, iron protoxide 8·54, magnesia 8·60, lime 1·33, soda 1·60, potash 0·73, water 1·81=100. A red tourmaline from Paris, Maine, afforded Fluorine 1·19, silica 41·16, boron trioxide (by loss) 8·93, alumina 41·83, manganese protoxide 0·95, magnesia 0·61, soda 1·37, potash 2·17, lithia 0·41, water 2·57 =100.

Tourmaline varies much in color owing to its variations in composition; the dark contain much iron and the light colors but little. Some of the varieties have received special names. *Rubellite* is *red* tourmaline; and *Indicolite, blue* and *bluish-black*. *Schorl* formerly included the common black tourmaline, but the name is not now used.

The presence of boron trioxide is the most remarkable point in the constitution of this mineral. The colorless, red, and pale-greenish kinds usually contain lithia. B.B. the darker varieties fuse with ease, and the lighter with difficulty. On mixing the powdered mineral with potassium bisulphate and fluor spar, and heating B.B., gives a green flame owing to the boron.

Diff. The black and the dark varieties generally, are readily distinguished by the form and lustre and absence of distinct cleavage, together with their difficult fusibility. The black when fractured often appear a little like a black resin. The brown variety resembles garnet or idocrase, but is more infusible. The red, green, and yellow varieties are distinguished from any species they resemble by the crystalline form, the prisms of tourmaline always having 3, 6, 9, or 12 prismatic sides (or some multiple of 3). The electric properties of the crystals, when heated, is another remarkable character of this mineral. The test for boron is always good.

Obs. Tourmalines are common in granite, gneiss, mica schist, chlorite schist, steatite, and granular limestone. They usually occur penetrating the rock. The black crystals are often highly polished and at times a foot in length, when perhaps of no larger dimensions than a pipe-stem, or even more slender. This mineral has also been observed in sandstones near basaltic or trap dikes.

Red and green tourmalines, over an inch in diameter and transparent, have been obtained at Paris and Hebron, Me., besides pink and blue crystals. These several varieties occur also, of less beauty, at Chesterfield and Goshen, Mass. Good black tourmalines are found at Norwich, New Braintree, and Carlisle, Mass.; Alsted, Acworth, and Saddleback Mountain, N. H.; Haddam and Monroe, Conn.; Saratoga and Edenville, N. Y.; Franklin and Newton, N. J.; near Unionville, Chester, and Middletown, Penn.; transparent brown at Hunterstown, Canada East; amber-colored at Fitzroy; black at Bathurst, and Elmsley, Canada West; fine greenish yellow at G. Calumet I.

Dark brown tourmalines are obtained at Orford, N. H.; in thin black crystals in mica at Grafton, N. H.; Monroe, Ct.; Gouverneur and Amity, N. Y.; Franklin and Newton, N. J. A fine cinnamon-brown variety occurs at Kingsbridge and Amity, Orange Co., N. Y. and also south in New Jersey. A gray or bluish-gray and green variety occurs near Edenville.

The word tourmaline is a corruption of the name used in Ceylon, whence it was first brought to Europe. ***Lyncurium*** is supposed to be the ancient name for common tourmaline; and the red variety was probably called ***hyacinth.***

The red tourmalines, when transparent and free from cracks, such as have been obtained at Paris, Me., are of great value and afford gems of remarkable beauty. They have all the richness of color and lustre belonging to the ruby, though measuring an inch across. The yellow tourmaline, from Ceylon is but little inferior to the real topaz, and is often sold for that gem. The green specimens, when clear and fine, are also valuable for gems. Plates from pellucid crystals cut in the direction of a vertical plane are much used for polariscopes.

Gehlenite. Tetragonal, like the scapolites, and grayish green in color. G.=2·9–3·07. Formula $Ca_3\overline{Al}O_{10}Si_2$ with some of the $\overline{Al}$ replaced by $\overline{Fe}$, and some of the Ca by Fe and Mg. From Mount Monzoni in the Fassa Valley.

Andalusite.

Trimetric. In rhombic prisms, which are nearly square; $I \wedge I = 90° 48'$. Cleavage lateral; sometimes distinct. Also massive and indistinctly coarse columnar, but never fine fibrous.

Colors gray and flesh-red. Lustre vitreous, or inclining to pearly. Translucent to opaque. Tough. H.=7·5. G.=3·1–3·3.

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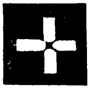

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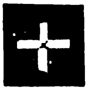

Composition. $\overline{Al}O_5Si$=Silica 36·9, alumina 63·1=100. B.B. infusible. Ignited after being moistened with cobalt nitrate assumes a blue color. Insoluble in acids.

Chiastolite and *macle* are names given to crystals of andalusite which show a tessellated or cruciform structure when broken across and polished. The above figures represent sections of crystals from Lancaster, Mass. The structure is owing to carbonaceous impurities distributed in the crystallizing process in a regular manner along the sides, edges and diagonals of the crystal. Their hardness is sometimes as low as 3.

Diff. Distinguished from pyroxene, scapolite, spodumene, and feldspar, by its infusibility, hardness, and form.

Obs. Most abundant in clay slate and mica slate, but occurring also in gneiss. Found in the Tyrol, Saxony, Bavaria, etc.; also in Westford, Mass.; Litchfield and Washington, Ct.; Bangor, Me.; Leiperville, Marple, and Springfield, Penn.; and chiastolite at Sterling and Lancaster, Mass., and near Bellows Falls, Vermont. This species was first found at Andalusia in Spain.

Fibrolite.—Sillimanite. Bucholzite.

Orthorhombic. In long, slender rhombic prisms, often much flattened, penetrating the gangue. $I \wedge I = 96°–98°$. A brilliant and easy cleavage, parallel to the longer diagonal. Also in masses, consisting of aggregated crystals or fibres. Color hair-brown or grayish brown. Lustre vitreous, inclining to pearly. Translucent crystals break easily. H.$=6–7$. G.$=3{\cdot}2–3{\cdot}3$.

Composition. $\text{Al}\,\text{O}_5\,\text{Si}$, as for andalusite, $=$Silica 36·9, alumina 63·1$=$100. Moistened with cobalt nitrate and ignited assumes a blue color. Infusible alone and with borax.

Diff. Distinguished from tremolite and the varieties generally of hornblende by its brilliant diagonal cleavage, and its infusibility; from kyanite and andalusite by its brilliant cleavage, its fibrous structure, and its rhombic crystalline form.

Obs. Found in gneiss, mica schist, and related metamorphic rocks. Occurs in the Tyrol, at Bodenmais in Bavaria; at the White Mountain Notch in N. H.; at Chester and near Norwich, Conn.; Yorktown, N. Y.; Chester, Birmingham, Concord, Darby, Penn.; in North Carolina; and elsewhere. Fibrolite was much used for stone implements in Western Europe in the "Stone age;" the locality whence the material was derived is not known.

Cyanite.—Kyanite. Disthene.

Triclinic. Usually in long thin-bladed crystals aggregated together, or penetrating the gangue. Sometimes in short and stout crystals. Lateral cleavage distinct. Sometimes fine fibrous.

Color usually light blue, sometimes having a blue centre with a white margin; sometimes white, gray, green, or even black. Lustre of flat face a little pearly. H. =5–7·5, greatest at the ends of the prisms, and least on the flat face of the prism. G. =3·45–3·7.

Composition. $Al\,O_5\,Si$, as for andalusite, =Silica 36·9, alumina 63·1=100. Blowpipe characters like those of andalusite.

Diff. Distinguished by its infusibility from varieties of the hornblende family. The short crystals have some resemblance to staurolite, but their sides and terminations are usually irregular ; they differ also in their cleavage and lustre. The thin-bladed habit of cyanite is very characteristic.

Obs. Found in gneiss and mica schist, and often accompanied by garnet and staurolite.

Occurs in long-bladed crystallizations at Chesterfield and Worthington, Mass.; at Litchfield and Washington, Conn.; near Philadelphia; near Wilmington, Delaware; and in Buckingham and Spotsylvania counties, Va. Short crystals (sometimes called improperly *fibrolite*) occur in gneiss at Bellows Falls, Vt., and at Westfield and Lancaster, Mass.

In Europe, at St. Gothard in Switzerland, at Greiner and Pfitsch in the Tyrol, in Styria, Carinthia, and Bohemia. Villa Rica in South America affords fine specimens.

The name cyanite is from the Greek *kuanos*, a dark-blue substance. It is also called *disthene*, in allusion to the unequal hardness in different directions, and when white, *rhætizite*.

Kyanite is sometimes used as a gem, and has some resemblance to sapphire.

Topaz.

Trimetric. $I \wedge I = 124° 17'$. Rhombic prisms, usually differently modified at the two extremities. $I \wedge I = 124° 17'$. Cleavage perfect parallel to the base.

Color pale yellow ; sometimes white, greenish, bluish, or reddish. Streak white. Lustre vitreous. Transparent to subtranslucent. Pyro-electric. H.=8. G=3·4–3·65.

Composition. $Al\,O_5\,Si$, with a part of the oxygen replaced by fluorine=Silica 16·2, silicon fluorid 28·1, alumina 55·7 =100. An analysis of one specimen afforded, Silica 34·24, alumina 57·45, fluorine 14·99. B.B. infusible. Some kinds become yellow or of a pink tint when heated. Moistened with cobalt nitrate and ignited assumes a fine blue color. Insoluble in acids.

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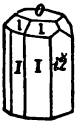

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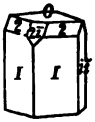

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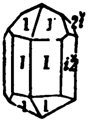

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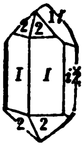


Diff. Topaz is readily distinguished from tourmaline and other minerals it resembles by its brilliant and easy basal cleavage.

Obs. Pycnite is a variety presenting a thin columnar structure and forming masses imbedded in quartz. The *Physalite* or *Pyrophysalite* of Hisinger is a coarse, nearly opaque variety, found in yellowish-white crystals of considerable dimensions. This variety intumesces when heated, and hence its name from *phusao,* to blow, and *pur,* fire.

Topaz is confined to metamorphic rocks or to veins intersecting them, and is often associated with tourmaline, beryl, and occasionally with apatite, fluorite, and tin ore.

Fine topazes are brought from the Uralian and Altai mountains, Siberia, and from Kamschatka, where they occur of green and blue colors. In Brazil they are found of a deep yellow color, either in veins or nests in lithomarge, or in loose crystals or pebbles. Magnificent crystals of a sky-blue color have been obtained in the district of Cairngorm, in Aberdeenshire. The tin mines of Schlackenwald, Zinnwald, and Ehrenfriedersdorf in Bohemia, St. Michael's Mount in Cornwall, etc., afford smaller crystals. The physalite variety occurs in crystals of immense size at Finbo, Sweden, in a granite quarry, and at Broddbo. A well-defined crystal from this locality, in the possession of the College of Mines of Stockholm, weighs eighty pounds. Altenberg in

Saxony, is the principal locality of pycnite. It is there associated with quartz and mica.

Trumbull, Conn., is a prominent locality of this species in the United States. It seldom affords fine transparent crystals, except of a small size; these are usually white, occasionally with a tinge of green or yellow. The large coarse crystals sometimes attain a diameter of several inches (rarely six or seven), but they are deficient in lustre, usually of a dull yellow color, though occasionally white, and often are nearly opaque. It is found also at Crowder's Mountain in N. C.; in Utah, in Thomas's Mountains, and in gold washings in Oregon.

The ancient *topazion* was found on an island in the Red Sea, which was often surrounded with fog, and therefore difficult to find. It was hence named from *topazo*, to seek. This name, like most of the mineralogical terms of the ancients, was applied to several distinct species. Pliny describes a statue of Arsinoe, the wife of Ptolemy Philadelphus, four cubits high, which was made of topazion, or topaz, but evidently not the topaz of the present day, nor chrysolite, which has been supposed to be the ancient topaz. It has been conjectured that it was a jasper or agate; others have supposed it to be prase or chrysoprase.

Topaz is employed in jewelry, and for this purpose its color is often altered by heat. The variety from Brazil assumes a pink or red hue, so nearly resembling the Balas ruby, that it can only be distinguished by the facility with which it becomes electric by friction. Beautiful crystals for the lapidary are brought from Minas Novas, in Brazil. When cut with facets and set in rings, they are readily mistaken, if viewed by daylight, for diamonds. From their peculiar limpidity, topaz pebbles are sometimes denominated *gouttes d'eau*.

The perfect cleavage of topaz makes it a poor substitute for emery.

Euclase.

Monoclinic. In oblique rhombic prisms, with cleavage highly perfect parallel to the clinodiagonal section, affording smooth polished faces.

Color pale green to white or colorless, pale blue. Lustre vitreous; transparent. Brittle. H.=7·5. G.=3·1. Pyroelectric.

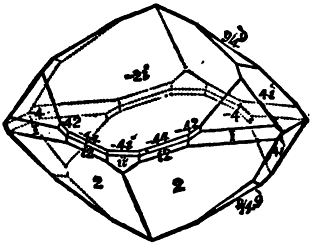
Composition. $H_2Be_2Al\,O_{10}\,Si_2$ = Silica 41·20, alumina 35·22, glucina 17·39, water 6·19 = 100. B.B. fuses with much difficulty to a white enamel; not acted on by acids.

Diff. The cleavage of this glassy mineral is, like that of topaz, very perfect, but is not basal. The cleavage distinguishes it from tourmaline and beryl.

Obs. Occurs in the Ural, and with topaz in Brazil.

The crystals of this mineral are elegant gems of themselves, but they are seldom cut for jewelry on account of their brittleness.

Datolite.—Datholite. Humboldtite.



Monoclinic. Crystals without distinct cleavage; small and glassy. Also botryoidal, with a columnar structure, and then called *botryolite.* Color white, occasionally grayish, greenish, yellowish, or reddish. Translucent. H.=5–5·5. G.=2·8–3.

Composition. $H_2Ca_2B_2\,O_{10}\,Si_2$ = Silica 37·5, boron trioxide 21·9, lime 35·0, water 5·6 = 100. Botryolite contains twice the proportion of water. B.B. becomes opaque, intumesces and melts easily to a glassy globule coloring the flame green. Decomposed by hydrochloric acid; the solution gelatinizes on evaporation.

Diff. Its glassy complex crystallizations, without cleavage, are unlike any other mineral that gelatinizes with acid. It is distinguished from minerals that it resembles also by tingeing the blowpipe-flame green.

Obs. Occurs in cavities in trap rocks and gneiss. Found in Scotland; at Andreasburg; at Baveno; Toggiana; also Bergen Hill, in N. J.; in Connecticut, at Roaring Brook, 14 miles from New Haven; and near Hartford, Berlin, Middlefield Falls, Conn.; also in great abundance at Eagle Harbor in the copper region, Lake Superior, and on Isle Royale; also near Santa Clara, Cal.

Homilite. **A black silicate of iron and calcium, resembling gadolinite, but affording from 15 to 18 per cent. of boracic acid with 32 of silica; formula $R_3B_2\,O_{10}\,Si_2$. From Brevig, Norway.**

Titanite.—Sphene.

Monoclinic. In very oblique rhombic prisms ; the lateral faces making angles often of 76° 7′, 113° 31′ ($I \wedge I$), 136° 12′ ($2 \wedge 2$), or 133° 52′. The crystals are usually thin with sharp edges. Cleavage in one direction sometimes perfect. Occasionally massive.

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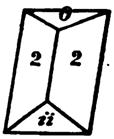

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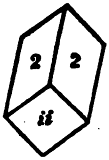

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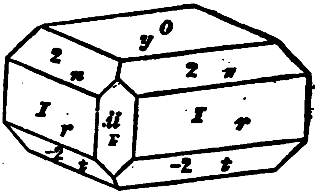

Color grayish-brown, ash-gray, brown to black; sometimes pale yellow to green; streak uncolored. Lustre adamantine to resinous. Transparent to opaque. H.=5–5·5. G.=3·2–3·6.

Composition. $CaTiO_5$ Si=Silica 30·6, titanium dioxide 40·82, lime 28·57=100 ; in dark brown and black crystals, some iron replaces part of the calcium. B.B. fuses with intumescence. Imperfectly decomposed by hydrochloric acid.

The dark varieties of this species were formerly called *titanite*, and the lighter *sphene*. The name *sphene* alludes to the wedge-shaped crystals, and is from the Greek *sphen*, wedge. *Greenovite* is a variety colored rose-red by manganese.

Diff. The thin wedge-like form of the crystals, in general, readily distinguish this species ; but some crystals are very complex.

Obs. Sphene occurs mostly in disseminated crystals in granite, gneiss, mica slate, syenyte, or granular limestone. It is usually associated with pyroxene and scapolite, and often with graphite. It has been found in volcanic rocks. The crystals are commonly $\frac{1}{4}$ to $\frac{1}{2}$ an inch long; but are sometimes 2 or more inches in length.

Foreign localities are Arendal in Norway ; at St. Gothard and Mont Blanc ; in Argyleshire and Galloway in Great Britain. Occurs in Canada, at Grenville and elsewhere ; New York, at Roger's Rock, on Lake George ; with graphite and pyroxene, at Gouverneur, near Natural Bridge in Lewis County (the variety called *Lederite*); in Orange County in Monroe, Edenville, Warwick, and Amity; near Peekskill in Westchester County, and near West Farms; in Massachusetts, at Lee, Bolton, and Pelham; in Connecticut, at Trumbull; in Maine, at Sanford, and Thomaston; in New Jersey, at Franklin; in Pennsylvania, near Attleboro', Bucks County; in Delaware, at Dixon's quarry, 7 miles from Wilmington; in Maryland, 25 miles from Baltimore, on the Gunpowder.

Guarinite. Like sphene in composition, but trimetric.

Keilhauite, or *Yttro-titanite.* Related to sphene. Brownish-black, with a grayish-brown powder. G.=3·69. H.=6·5. Fuses easily. Affords Silica 30·0, titanic acid 29 0, yttria 9·6, lime 18·9, iron sesquioxide 6·4, alumina 6·1. From Arendal, Norway.

Tscheffkinite. Near Keilhauite. From the Ilmen Mountains.

Staurolite.—Staurotide.

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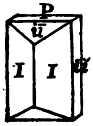

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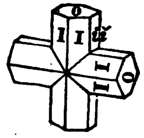

Trimetric. $I \wedge I = 129° 20'$. Cleavage imperfect. Usually in cruciform twin crystals. Figure 2 is a common kind; another crosses at an acute angle near 60°; and another, of rare occurrence, consists of three crystals intersecting at angles near 60°. Never in massive forms or slender crystallizations.

Color dark brown or black. Lustre vitreous, inclining to resinous; sometimes bright, but often dull. Translucent to opaque. H.=7–7·5. G.=3·4–3·8.

Composition. $H_2R_3Al_6O_{34}Si_6$=Silica 30·37, alumina 51·92, iron protoxide 13·66, magnesia 2·53, water 1·52=100. B.B. infusible. Insoluble in acids.

Diff. Distinguished from tourmaline and garnet by its infusibility and form.

Obs. Found in mica slate and gneiss, in imbedded crystals.

Occurs very abundant through the mica schist of New England: Franconia, Vt.; Windham, Me.; Lisbon, N. H.; Chesterfield, Mass; Bolton and Tolland, Ct.; also on the Wichichon, eight miles from Philadelphia; at Canton, and in Fannin County, Georgia. Mt. Campione in Switzerland, and the Greiner Mountain, Tyrol, are noted foreign localities.

The name staurolite is from the Greek *stauros*, a cross.

Schorlomite. Black, and often irised tarnished. Streak grayish-black. H.=7–7·5. G.=3·80. Fuses readily on charcoal. Easily decomposed by the acids, and gelatinizes. Contains much titanium, with iron, lime, and silica. From Magnet Cove, Arkansas, and Kaiserstuhlgebirge, Breisgau.

B. HYDROUS SILICATES.

The three sections under which the Hydrous Silicates are arranged are the following:

I. General Section. Under this section there are included: (1) *Bisilicates*—Pectolite, Laumontite, Apophylite, etc.; (2) *Unisilicates*—Prehnite, Calamine, etc.; and (3) *Subsilicates*—as Allophane, and some related species.

II. Zeolite Section. The minerals included are feldspar-like in constituents, and apparently so in quantivalent (or oxygen) ratio; the basic elements being, as in the feldspars, (1) aluminum, and (2) the metals of the alkalis K, Na, and of the alkaline earths Ca, Ba, with also Sr, to the almost total exclusion of magnesium and iron.

III. Margarophyllite Section. This section embraces species having a micaceous or thin-foliated structure when crystallized, with the surface of the folia pearly, and the plane angle of the base of the prism 120°. Whether crystallized or massive the feel is greasy, at least when pulverized. It comprises (1) Bisilicates: including Talc and Pyrophyllite, which are atomically and physically similar species, although the former is a magnesium silicate, and the latter an aluminum silicate; (2) Non-alkaline Unisilicates, including Kaolinite and Serpentine, which have a similar difference in constituents to the preceding with the same likeness in composition, and also some related species; (3) Alkaline Unisilicates: as, Pinite and the Hydrous Micas, which are species containing potassium or sodium as an essential constituent; (4) the Chlorite Group, the species of which are mostly Subsilicates.

I. GENERAL SECTION.

Pectolite.

Monoclinic, isomorphous with wollastonite. Usually in aggregations of acicular crystals, or fibrous-massive, radiate, stellate. Color white, or grayish. Translucent to opaque. Tough. H.=5. G.=2·68–2·8.

Composition. $R\,O_3\,Si$, in which $R=\frac{1}{6}H_2\,\frac{1}{6}Na_2\,\frac{4}{6}Ca$, = Silica 54·2, lime 33·8, soda 9·3, water 2·7=100. In the closed tube yields water. B.B. easily fusible. Decomposed by hydrochloric acid, and the solution gelatinizes somewhat when evaporated.

Diff. Its fibrous forms and its blowpipe reactions are distinctive.

Obs. Occurs mostly in cavities or seams in trap or basic eruptive rocks, and occasionally in other rocks. Found at Ratho Quarry, near Edinburgh, Scotland; at Kilsyth; Isle of Skye; in the Tyrol; in fine specimens at Bergen Hill, N. J.; a compact variety at Isle Royale, Lake Superior.

Okenite and Gyrolite are related hydrous calcium silicates. Okenite is from the Faroe Islands, Iceland, and Greenland, and gyrolite from the Isle of Skye, and from Nova Scotia 25 miles southwest of Cape Blomidon.

Laumontite.

Monoclinic, with the angles nearly of pyroxene; $I \wedge I=$ 86° 16′. Cleavage parallel to the clinodiagonal section and to I perfect. Also massive, with a radiating or divergent structure.

Color white, passing into yellow or gray, sometimes red. Lustre vitreous, inclining to pearly on the cleavage face. Transparent to translucent. H.=3·5–4. G.=2·25–2·36. Becomes opaque on exposure through loss of water, and readily crumbles.

Composition. $CaAl\,O_{12}Si_4+4\,aq$=Silica 50·0, alumina 21·8, lime 11·9, water 16·3=100. B.B. swells up and fuses easily to a white enamel. Decomposed by hydrochloric acid. and the solution gelatinizes on evaporation.

Diff. The alteration this species undergoes on exposure to the air at once distinguishes it. This result may be prevented with cabinet specimens, by dipping them into a solution of gum arabic.

Obs. Found in the veins and cavities of trap rocks and also in gneiss, porphyry. Occurs at the Faroe Islands; Kilpatrick Hills, near Glasgow; Disco, Greenland; St. Gothard, Switzerland; Peter's Point, Nova Scotia; Phippsburg, Me.; Charlestown syenite quarries, Mass.; Bergen Hill, N. J.; the Copper region, Lake Superior, and Isle Royale.

Leonhardite. Probably Laumontite which has lost part of its water by alteration. It resembles that species in crystallization and in most of its characters, but differs in being less efflorescent on exposure to a dry atmosphere. Analyses of specimens from Copper Falls, Lake Superior, have obtained, Silica 55·50, alumina 21·19, lime 10·56, water 11·93 = 99·68. The Copper Falls variety alters little on exposure. Reported also from trachyte at Schemnitz, in Hungary, and from Pfitsch in the Tyrol.

Apophyllite.

Dimetric. In square octahedrons, prisms, and tables. Cleavage parallel with the base highly perfect. Massive and foliated. Color white or grayish; sometimes with a shade of green, yellow, or red. Lustre of *O* pearly: of the other faces vitreous. Transparent to opaque. H.=4·5–5. G.=2·3–2·4.

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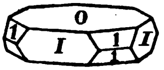

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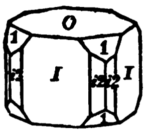

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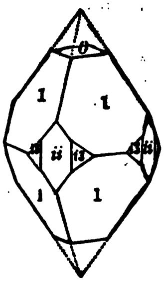

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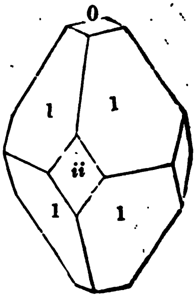

Composition. A silicate of calcium and hydrogen combined, with potassium fluoride and water, of the formula $(\frac{1}{2}H_2\frac{1}{2}Ca)\,O_2\,Si + \frac{1}{8}KF + \frac{1}{2}aq$=Silica 52·97, lime 24·72, potash 5·20, water 15·90, fluorine 2·10=100·89. B.B. exfoliates, colors the flame violet (owing to the potash), and fuses very easily to a white enamel. In the closed tube yields water which has an acid reaction. Decomposed by hydrochloric acid with the separation of slimy silica.

Diff. The pearly basal cleavage and the forms of its glassy crystals at once distinguish it from the preceding species. The prisms are sometimes almost cubes, with the angles cut off by the planes of the pyramid ; but the difference in the lustre of the prismatic and basal faces shows that it is dimetric.

The name alludes to its exfoliation before the blowpipe.

Obs. Found in amygdaloidal trap and basalt.

Occurs in fine crystallizations at Peter's Point and Partridge Island, Nova Scotia, at Bergen Hill, N. J., the Cliff Mine, Lake Superior region.

Catapleiite. **A hydrous zirconium and sodium silicate, from Norway.**

Dioptase **and** ***Chrysocolla.*** **Hydrous copper silicates. See p. 141.**

Picrosmine, Pyrallolite, Picrophyll, Traversellite, Pitkarandite, Strakonitzite, Monradite, **are names of varieties of pyroxene in different stages of alteration.** ***Xylotine*** **is probably altered asbestus.**

Prehnite.

Trimetric. $I \wedge I = 99° 56'$. Cleavage basal. Sometimes in six-sided prisms, rounded so as to be barrel-shaped, and composed of a series of united plates ; also in thin rhombic or hexagonal plates. Usually reniform and botryoidal, with a crystalline surface ; texture compact.

Color light green to colorless. Lustre vitreous, except the face *O*, which is somewhat pearly. Subtransparent to translucent. H.=6–6·5. G.=2·8–2·96.

Composition. $H_2Ca_2AlO_{12}Si_3$=Silica 43·6, alumina 24·9, lime 27·1, water 4·4=100. B.B. fuses very easily to an enamel-like glass. Decomposed by hydrochloric acid, leaving a residue of silica in light flakes, but the solution does not gelatinize. Yields a little water when heated in a closed tube.

Diff. Distinguished from beryl, green quartz, and chalcedony by fusing before the blowpipe, and from the zeolites by its superior hardness.

Obs. Found in the cavities of trap, gneiss, and granite.

Occurs in the trap rocks of the Connecticut Valley, and at Paterson and Bergen Hill, N. J. ; in gneiss at Bellows Falls, Vt. ; in syenyte at Charlestown, Mass. ; and very abundant, forming large veins, in the Copper region of Lake Superior, three miles south of Cat Harbor, and elsewhere.

The Fassa Valley in the Tyrol, St. Christophe in Dauphiny, and the Salisbury Crag, near Edinburgh, are some of the foreign localities.

Prehnite receives a handsome polish and is sometimes used for inlaid work. In China it is polished for ornaments, and large slabs have been cut from masses brought from there.

Chlorastrolite and *Zonochlorite*, from the Lake Superior region, are impure prehnite.

Chalcomorphite. A hydrous calcium silicate, from calcite in cavities of lava, containing but 25·4 per cent. of silica.

Gismondite (*Zeagonite*). A hydrous lime-aluminum silicate, occurring in trimetric crystals resembling square octahedrons; found in lava at Capo di Bove, near Rome.

Edingtonite. A hydrous barium-aluminum silicate. Occurring in crystals and massive. From the Kilpatrick Hills, with harmotome.

Carpholite. A manganese-aluminum silicate, occurring in silky, yellow, radiated tufts. From the tin mines of Schlackenwald.

Pyrosmalite. A manganese-iron silicate and chloride, from Sweden.

Calamine. A hydrous zinc unisilicate. See p. 157.

Villarsite. Probably altered chrysolite.

Cerite, Tritomite, Erdmannite, are cerium and lanthanum silicates.

Thorite (*Orangite*) and *Eucrasite,* are thorium silicates; the latter hydrous.

Allophane.

In amorphous incrustations, with a smooth small-mammillary surface, and often hyalite-like, and sometimes pulverulent. Color pale bluish-white to greenish-white, and deep green; also brown, yellow, colorless. Translucent. H.=3. G.=1·85–1·89.

Composition. Mostly $Al\,O_5\,Si + 6$ (or 5) aq. Silica 23·75, alumina 40·62, water 35·63=100. In the closed tube yields much water. B.B. infusible, but crumbles. A blue color with cobalt solution, and a jelly with hydrochloric acid.

Occurs in Saxony; at the Chessy Copper Mine near Lyons; at a copper mine in Bohemia; with limonite in Moravia; in Old Chalk Pits near Woolwich, England; with gibbsite in limonite beds in Richmond, Mass.; at the copper mine of Bristol, Conn.; at Morgantown, Pa.; copper mines of Polk County, Tenn.

Collyrite. A hydrous aluminum silicate containing only 14 to 15 per cent. of silica, and 35 to 40 of water; and *Schrötterite* is another with 11 to 12 per cent. of silica. The latter has been reported as occurring, as a gum-like incrustation, at the falls of Little River, on Sand Mountain, Cherokee County, Alabama. *Scarbroite* is a related mineral of doubtful nature.

II. ZEOLITE SECTION.

The species of the Zeolite Section have been described as having some relation to the feldspars in constitution. In the feldspars, as explained on page 273, the following ratios, for the protoxides, alumina, and silica which analyses afford, occur: 1:3:4, 1:3:6, 1:3:8, 1:3:9, 1:3:10, 1:3:12. So, among the zeolites, if the water be left out of consideration, these are the ratios: 1:3:4 (in Thomsonite), 1:3:6 (Natrolite, Scolecite, etc.), 1:3:8 (Analcite, Chabazite, etc.), 1:3:10 (Harmotome), 1:3:12 (Stilbite, Heulandite, etc.). This fact, added to the absence or nearly total absence of magnesium and iron, and presence instead of Na_2, K_2, Ca, Ba, make out a distinct relation to the feldspars, whatever may be the part which the water sustains in the compounds. Besides barium, strontium is sometimes present, an element not yet known to characterize a species of feldspar.

These minerals were called *zeolites* because they generally fuse easily with intumescence before the blowpipe, the term being derived from the Greek *zeo*, to *boil*. Among those described beyond, Heulandite and Stilbite, have a strong pearly cleavage, and the latter is often in pearly radiations; Natrolite, Scolecite, are fibrous and radiated, or in very slender prisms; Thomsonite occurs either radiated, or compact, or in short crystals; while Harmotome, Analcite, and Chabazite, and the related Gmelinite, occur only in short or stout glassy crystals, those of chabazite looking sometimes like cubes.

The zeolites are sometimes called *trap* minerals, because they are often found in the cavities or fissures of amygdaloidal trap as well as related basic eruptive rocks. Yet they occur also occasionally in fissures or cavities in gneiss, granite, and other metamorphic rocks. They are not the original minerals of any of these rocks; but the results of alteration of portions of them near the little cavities or fissures in which the minerals occur; and part were made while the rock was still hot, and as cooling went forward. Besides true zeolites, such cavities often contain also Laumontite (p. 293), noted for its tendency to crumble on exposure; Pectolite and Okenite (p. 293), which are fibrous like Natrolite and Scolecite; Apophyllite (p. 294), having one pearly cleavage like heulandite and stilbite; Prehnite (p. 295), usually apple-green; Datolite (p. 289), in stoutish glassy complex crystals, or in smooth botryoidal forms; Aragonite (p. 218), sometimes radiated fibrous, and Calcite (p. 215) with its three directions of like easy cleavage, both effervescing with hydrochloric acid; Siderite (p. 185), in spheroidal or other forms; Chlorite (p. 316), of dark olive-green color; and Quartz, either in crystals, or as chalcedony, agate, or carnelian, and in either case easily distinguished by the hardness, absence of cleavage, and infusibility. Of all these species Calcite and Quartz are the most common. Of rarer occurrence than the above, there are Orthoclase, Asphaltic coal, Copper, etc.

All the zeolites yield water in the closed tube, and many of them gelatinize with hydrochloric acid.

Thomsonite.

Trimetric. In right rectangular prisms. Usually in masses having a radiated structure within, and consisting of long fibres, or acicular crystals; also amorphous.

Color snow-white; impure varieties brown. Lustre vitreous, inclining to pearly. Transparent to translucent. H.=5–5. Brittle. G.=2·3–2·4.

Composition. $(\text{Ca},\text{Na}_2)\cancel{\text{A}}\text{l}\,\text{O}_8\,\text{Si}_2+2\tfrac{1}{2}\,\text{aq}$=Silica 38·09, alumina 31·62, lime 12·60, soda 4·62, water 13·40=100·20.

B.B. fuses very easily to a white enamel. Decomposed by hydrochloric acid; the solution gelatinizes when evaporated.

Diff. Distinguished from natrolite by its fusion to an opaque and not to a glassy globule.

Obs. Occurs in amygdaloid, near Kilpatrick, Scotland; in lavas at Vesuvius, *Comptonite;* in clinkstone in Bohemia; the Tyrol, etc.; at Peter's Point, Nova Scotia, in trap; a massive variety, called *Ozarkite,* at Magnet Cove, Ark.

The species was named after Dr. Thomas Thomson, of Glasgow.

Natrolite.

Trimetric. In slender prisms, terminated by a short pyramid; $I \wedge I = 91°$; $1 \wedge 1$ over $x = 143° 20'$. Also in globular, stellated, and divergent groups, consisting of delicate acicular fibres, the fibres often terminating in acicular prismatic crystals.

Color white, or inclining to yellow, gray, or red. Lustre vitreous. Transparent to translucent. H.$=5$–$5{\cdot}5$. G.$=2{\cdot}17$–$2{\cdot}25$. Brittle.

Composition. $Na_2Al\,O_{10}\,Si_3+2$ aq = Silica 47·29, alumina 26·06, soda 16·30, water 9·45=100. B.B. fuses easily and quietly to a clear glass; a fine splinter melts in a candle flame. Decomposed by hydrochloric acid, and the solution gelatinizes on evaporation.

Diff. Distinguished from scolecite by its quiet fusion.

Obs. Found in amygdaloidal trap, basalt and volcanic rocks; sometimes in seams in granitic rocks. The name natrolite is from *natron*, soda.

Occurs in Bohemia; Auvergne; Fassathal, Tyrol; at Glen Farg in Fifeshire; in Dumbartonshire; Nova Scotia; Bergen Hill, N. J.

Scolecite. Resembles natrolite, and differs in containing *lime* in place of *soda*; also in having its slender rhombic glassy prisms longitudinally twinned, as is shown by the meeting of two ranges of striæ at an angle along or near the central line of opposite prismatic planes. The lustre is vitreous or a little pearly. B.B. it curls up like a worm (whence the name from the Greek *skolex*, a *worm*) and then melts. From Staffa, Iceland, Finland, Hindostan.

Mesolite. Another related species.

Analcite.

Dimetric or Trimetric. Occurs usually in trapezohedron (fig. 1, also fig. 2).

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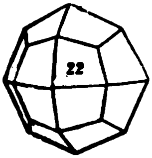

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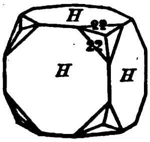


The appearance sometimes seen in polarized light is shown in figure 7, page 69 On account of this peculiar behavior and indications of a compound structure obtained in a microscopic study of thin slices, it has been suspected to be dimetric like leucite, or else trimetric like phillipsite, although the forms of the crystals are apparently isometric. Often colorless and transparent, also milk-white, grayish and reddish-white, and sometimes opaque. Lustre vitreous. H.=5–5·5. G.=2·25.

Composition. $Na_2Al\,O_{12}Si_4+2aq$ = Silica 54·47, alumina 23·29, soda 14·07, water 8·17=100. B.B. fuses easily to a colorless glass. Decomposed by hydrochloric acid; and the silica separates in gelatinous lumps.

Diff. Characterized by its crystallization, without cleavage. Distinguished from quartz and leucite by giving water in a closed glass tube; from calcite by its fusibility, and by not effervescing with acids; from chabazite and its varieties by fusing *without* intumescence to a *glassy* globule, and by the crystalline form.

Obs. Found in cavities and seams in amygdaloidal trap, basalt and other eruptive rocks, and sometimes in granite, syenyte and gneiss.

Occurs in fine crystallizations in Nova Scotia; also at Bergen Hill, N. J.; Perry, Me.; and in the trap of the Copper region, Lake Superior. The Faroe Islands, Iceland; Glen Farg, near Edinburgh; Kilmalcolm, the Campsie Hills, and Antrim; the Vicentine; the Hartz at Andreasberg; Sicily, and Vesuvius, are some of the foreign localities.

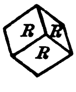
The name *analcite* is from the Greek, *analkis*, weak, alluding to its weak electric power when heated or rubbed.

Eudnophite. Near analcite. From Norway.

Faujasite. In isometric octahedrons. From the Kaiserstuhl, Baden.

Chabazite.

Rhombohedral. Often in rhombohedrons, much resembling cubes. $R : R=94° 46'$. Cleavage parallel to R. Also in complex modifications of this form. Never massive or fibrous.



Color white, also yellowish, and flesh-red or red. Lustre vitreous. Transparent to translucent. H.=4–5. G.=2·08–2·19.

The red chabazite of Nova Scotia has been called *Acadialite.*

Composition. $CaAl\,O_{12}\,Si_4+6aq$, with a little Na_2 or K_2 in place of part of the Ca. The Nova Scotia acadialite afforded

Silica 52·20, alumina 18·27, lime 6·58, soda and potash 2·12, water 20·52. B.B. intumesces and fuses to a nearly opaque bead. Decomposed by hydrochloric acid, with the separation of slimy silica. In the closed tube gives water. *Phacolite* is a variety in complex glassy crystals.

Diff. The nearly cubical form often presented by the crystals of chabazite is a striking character. It is distinguished from analcite as stated under that species; from calcite by its hardness and action with acids; from fluorite by its form and cleavage, and its showing no phosphorescence.

Obs. Found in trap and occasionally in gneiss, syenyte, and other rocks. Chabazite is met with in the trap of Connecticut Valley, but in poor specimens; also at Hadlyme and Stonington, Conn.; Charlestown, Mass.; Bergen Hill, N. J.; Piermont, N. Y.; Jones's Falls, near Baltimore (*Haydenite*). Nova Scotia affords common chabazite, and also the acadialite in abundance. The Faroe Islands, Iceland, and Giant's Causeway, are some of the foreign localities; also the County of Antrim, Ireland.

Herschelite. Near chabazite, if not identical with it. From Sicily.

Gmelinite. Closely resembles some chabazite, but its crystals are usually hexagonal rather than rhombohedral in appearance. Formula $(Na_2,Ca)Al_2O_{12}Si_4$. A Bergen Hill specimen afforded Silica 48·67, alumina 18·72, lime 2·60, soda 9·14, water 21·35=100·48. Gelatinizes with hydrochloric acid, but in other respects resembles chabazite. Occurs at Andreasberg; in Antrim, Ireland; in Skye; at Bergen Hill, N. J.; in Nova Scotia at Cape Blomidon. Named after the chemist, Gmelin.

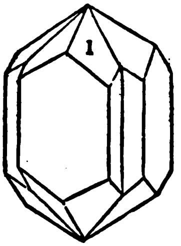
Levynite (*Levyne*). Rhombohedral, and somewhat resembling gmelinite in its crystals; excluding the water, having the quantivalent ratio of labradorite, 1 : 3 : 6. Colorless, white, grayish, reddish. From Iceland, Greenland, Antrim, Londonderry, Hartfield Moss near Glasgow. Named after the crystallographer, Lévy.

Harmotome.

Monoclinic. Unknown except in compound crystals; and commonly in forms similar to the annexed figure; also in compound rhombic prisms.

Color white; sometimes gray, yellow, red, or brownish. Subtransparent to translucent. Lustre vitreous. H.=4·5. G.=2·45.

Composition. $BaAlO_{14}Si_5 + 5aq$ = Silica 46·5, alumina 15·9, baryta 23·7, water 13·9=100; but a little of the baryta replaced by potash. B.B. whitens, crumbles, and fuses quietly to a white translucent glass. Gives water in a closed glass tube. Partially decomposed by hydrochloric acid, and if sulphuric acid be added to the solution, a heavy white precipitate of barium sulphate is formed. Some varieties phosphoresce when heated.



Diff. Its twin crystals, when distinct, cannot be mistaken for any other species except phillipsite. Much more fusible than glassy feldspar or scapolite; does not gelatinize in acids like thomsonite.

Obs. Occurs in amygdaloidal trap, and in trachyte and phonolyte, also in gneiss, and metalliferous veins. Fine crystallizations are found at Strontian in Scotland, and in Dumbartonshire; Andreasberg in the Hartz; Kongsberg in Norway. Has been found in seams in the gneiss of the upper part of New York Island.

The name harmotome is from the Greek *harmos,* a joint, and *temno,* to cleave.

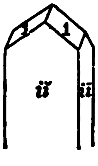
Phillipsite. Near harmotome in its cruciform crystals and other characters; but differing in containing lime in place of baryta. It differs also in gelatinizing with acids and in fusing with some intumescence. It also occurs in sheaf-like aggregations and in radiated crystallizations. From the Giant's Causeway, Capo di Bove, Vesuvius, Sicily, Iceland.

Epistilbite. A hydrous silicate of alumina and lime. Occurs in thin rhombic prisms, of a white color, with a perfect pearly cleavage like stilbite. H.=4–4·5. G.=2·25. Before the blowpipe froths and forms a vesicular enamel. Does not gelatinize. From Iceland and Hindostan, and sparingly at Bergen Hill, N. J.

Bravaisite. Supposed to be a zeolite; it has potassium, magnesium and iron as the protoxide bases.

Stilbite.

In pyramidally terminated rectangular prisms usually flattened parallel to the face *i-ĭ*, which is the direction of cleavage and is very pearly in lustre. $1 \wedge 1 = 119^\circ\ 16'$, and 114°. Also in sheaf-like aggregations, and thin lamellar and columnar; also in pearly radiated crystallizations.



Color white; sometimes yellow, brown or red. Subtransparent to translucent. H.=3·5–4. G.=2·1–2·15.

Composition. $CaAlO_{16}Si_6+6aq$=Silica 57·4, alumina 16·5, lime 8·9, water 17·2=100; but with a little Na_2 or K_2 in place of part of the Ca. B.B. exfoliates, swells up, and curves into fan-like forms, and fuses to a white enamel. Decomposed by hydrochloric acid without gelatinizing.

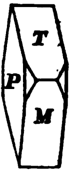
Diff. It cannot be scratched with the thumb-nail, like gypsum. It is distinguished from heulandite by its crystals.

Obs. Occurs mostly in trap-rocks; also on gneiss and granite. Found on the Faroe Ids.; Isle of Skye; Isle of Arran, and elsewhere, Scotland; Andreasberg, Hartz; the Vendayah Mts., Hindostan. Found sparingly at the Chester and Charlestown syenite quarries, Mass.; at New Haven, Thatchersville and Hadlyme, Conn., and other points in the Connecticut Valley trap; at Phillipstown, N. Y.; at Bergen Hill, N. J.; in trap, in the copper region of Lake Superior; in beautiful crystallizations at various points in Nova Scotia.

The name stilbite is derived from the Greek *stilbè* lustre. It has also been called *desmine*, and in Germany *heulandite*, where heulandite has been called *stilbite*.

Heulandite.

Monoclinic. In right rhomboidal prisms like the figure, with perfect pearly cleavage parallel to P and other planes vitreous in lustre. P on M or T=90°; M on T =129° 40′. Color white; sometimes reddish, gray, brown. Transparent to subtranslucent. Folia brittle. H.=3·5–4. G.=2·17–2·2.



Composition. $CaAlO_{16}Si_6+5aq$=Silica 59·1, alumina 16·9, lime 9·22, water 14·8=100. Contains 1 to 2 per cent. of Na_2 or K_2 in place of part of the Ca. Blowpipe characters like those of stilbite. Intumesces and fuses, and becomes phosphorescent. Dissolves in acid without gelatinizing.

Diff. The very pearly lustre of the cleavage face is a marked characteristic. Distinguished from gypsum by its hardness; from apophyllite and stilbite by its crystals; and from the latter species also in not occurring in radiated crystallizations.

Obs. Found in amygdaloidal cavities and fissures in trap; occasionally in gneiss, and in some metalliferous veins; in large crystallizations at Berufiord, Iceland; and Vendayah Mts., Hindostan; also at Isle Skye; near Glasgow; Fassa Valley; at Bergen Hill, N. J., in trap; at Hadlyme, Conn., and Chester, Massachusetts, on gneiss; near Baltimore, on a syenitic schist (*Beaumontite*); at Peter's Point and Cape Blomidon, and other places in Nova Scotia, in trap.

The species was named by Brooke after Mr. Heuland, of London.

Brewsterite. Crystals monoclinic with a perfect pearly cleavage like heulandite; but $M : T = 93^\circ\ 40'$. H.=4½–5. G.=2·45. The formula is analogous to that of heulandite, but baryta and strontia take the place of the lime and soda.

Epistilbite. Composition like that of heulandite, but occurs in short and very obtuse rhombic prisms, ($I \wedge I = 135^\circ\ 10'$), at Skye; the Faroe Ids., in Iceland; at Margaretville, in Nova Scotia.

Mordenite. Fibrous mineral from Morden, Nova Scotia.

Pilinite. In slender needles, from Silesia.

Foresite. Near stilbite. From Elba.

III. MARGAROPHYLLITE SECTION.

Talc.

Trimetric. In right rhombic or hexagonal prisms. $I \wedge I = 120^\circ$. Usually in pearly foliated masses, separating easily into thin translucent folia. Sometimes stellate, or divergent, consisting of radiating laminæ. Often massive, consisting of minute pearly scales; also crystalline granular, or of a fine impalpable texture.

Lustre eminently pearly, and feel unctuous. Color some shade of light green or greenish white; occasionally silvery white; also grayish green and dark olive-green. H.=1–1·5; easily impressed with the nail. G.=2·5–2·8. Laminæ flexible, but not elastic.

There are the following *varieties:*

Foliated Talc. The pure foliated talc, of a white or greenish-white color.

Soapstone or *Steatite.* Gray or grayish green, and either massive, crystalline granular, or impalpable; very greasy to the touch. French chalk is a milk-white variety, with a pearly lustre. *Potstone* or *Lapis Ollaris* is impure soapstone of grayish-green and dark-green colors, and slaty structure.

Indurated Talc, is a slaty talc, of compact texture, and above the usual hardness, owing to impurities.

Rensselaerite. A compact crypto-crystalline rock, from St. Lawrence and Jefferson counties, N. Y., of white, yellow, or grayish-white colors, and even black. It has sometimes the form and cleavage of pyroxene, and is in part at least a product of the alteration of that mineral.

Composition. $\frac{1}{5}H_2\,\frac{4}{5}Mg\,O_3\,Si$ = Silica 62·8, magnesia 33·5, water 3·7=100. It usually contains a little iron replacing magnesium. B.B. infusible. Moistened with cobalt nitrate assumes a pink tint. Not acted upon by hydrochloric acid. In closed tube gives a little water, but not till highly heated.

Diff. The softness, unctuous feel, foliated structure, when crystallized, and pearly lustre of talc are good characteristics. It differs from mica also in being inelastic, although flexible ; from chlorite, kaolinite, and serpentine in yielding little water when heated in a glass tube. Only the massive varieties resemble the last-mentioned species, and chlorite has a dark olive-green color. Pyrophyllite, which cannot be distinguished in some of its varieties from talc, becomes dark blue when moistened with cobalt nitrate and ignited.

Obs. Occurs in Cornwall, near Lizard Point ; at Portsoy in Scotland ; at Croky Head, Ireland ; in the Greiner Mountain, Saltzburg. Handsome foliated talc occurs at Bridgewater, Vt. ; Smithfield, R. I. ; Dexter, Me. ; Lockwood, Newton and Sparta, N. J., and Amity, N. Y. On Staten Island, near the Quarantine, both the common and indurated are obtained ; at Cooptown, Md., green, blue, and rose-colored talc occur. *Steatite* or soapstone is abundant, and is quarried at Grafton, Vt., and an adjacent town ; at Francestown and Orford, N. H. It also occurs at Keene and Richmond, N. H. ; at Marlboro' and New Fane, Vt. ; at Middlefield, Mass. ; in Loudon County, Va., and at many other places.

Steatite may be sawn into slabs and turned in a lathe. It is used for firestones in furnaces and stoves, and fire-places. It receives a polish after being heated, and has then a deep olive-green color. The finer kinds are made into images in China, and into inkstands and other forms in other countries. Potstone is worked into vessels for culinary purposes in Lombardy. The harder kinds are cut into gas jets. Steatite is also used in the manufacture of porcelain ; it makes the biscuit semi-transparent, but brittle and apt to break with slight changes of heat. It forms a polishing material for serpentine, alabaster and glass. "French chalk" is used for removing grease-spots from cloth, as well as for tracing on cloth. When ground up, soapstone is employed for diminishing the friction of machinery.

Pyrophyllite.—Agalmatolite, in part.

Near talc in crystallization, cleavage, its occurrence in fine-grained massive forms, its greasy feel, its white to pale-green colors, varying to yellowish, its feeble degree of hardness (1–2). The folia are sometimes radiated. G.=2·75–2·92.

Composition. An *aluminous* bisilicate, instead of a magnesian, for the most part of the formula, $\text{Al}\,\text{O}, \text{Si}_3$. The Chesterfield, S. C., mineral afforded Genth, Silica 64·82, alumina 24·48, iron sesquioxide 0·96, magnesia 0·33, lime 0·55, water 5·25=100·39. B.B. whitens and fuses with difficulty on the edges. Gives a deep blue color with cobalt solution. Yields water in the closed tube. Radiated varieties exfoliate in fan-like forms.

Obs. Compact pyrophyllite is the chief constituent of a kind of slate or schist, which is used for slate pencils, and hence is called *pencil-stone.* Occurs in the Urals; at Westana in Sweden; in Elfdalen, with cyanite; foliated, in North Carolina, in Cottonstone Mountain; in South Carolina, in Chesterfield District, with lazulite and cyanite; Georgia, in Lincoln County, on Graves Mountain; in Arkansas, near Little Rock; compact slaty in the Deep River region, N. C., and at Carbonton, Moore County, N. C.

Sepiolite.—Meerschaum of the Germans.

Usually compact, of a fine earthy texture, with a smooth feel, and white or whitish color; also fibrous, white to bluish-green in color. H.=2–2·5. The earthy variety floats on water.

Composition. $\frac{1}{3}\text{H}_2\,\frac{2}{3}\text{Mg}\,\text{O}_3\,\text{Si} + 1\frac{1}{2}\,\text{aq}$ = Silica 60·8, magnesia 27·1, water 12·1=100. B.B. infusible, or fuses with great difficulty on the thin edges. Much water in a closed tube. A pink color with cobalt solution.

Occurs in Asia Minor in masses in stratified earthy deposits, and is extensively used for pipe bowls; also found in

Greece, Moravia, Spain, etc. ; also in fibrous seams at a silver mine in Utah.

Aphrodite. Similar to the preceding. $MgO_3Si+\frac{3}{4}H$. From Sweden. *Cimolite*, a clay from the Island of Argentiera, Kimole of the Greeks. *Smectite*, a kind of "Fuller's Earth," a name given to unctuous clays used in fulling cloth. *Montmorillonite*, *Stolpenite*, and *Steargillite*, are related clay-like minerals.

Glauconite.—Green Earth.

In dark olive-green to yellowish-green grains, or granular masses, with dull lustre. H.=2. G.=2·2–2·4.

Composition. Essentially a silicate of iron and potassium. Formula $R\bar{R}\ O_{12}Si_4$, in which R is mainly Fe and K, with sometimes Mg ; and $\bar{R}$ is $\bar{Al}$, but sometimes largely $\bar{Fe}$. Analyses give mostly 50–58 per cent. silica, 20–24 iron protoxide, 4–12 of potash and 8–12 of water. B.B. fuses easily to a magnetic glass. Yields water in a closed tube.

Obs. In a more or less pure state it forms thick beds in the Cretaceous formation, and also in the Lower Tertiary of New Jersey ; also occurs in other older rock formations down to the Lower Silurian. Found also, first by Pourtales, in the pores of corals and cavities of Rhizopod shells over the existing sea-bottom, showing it to be a marine product, and one now in progress of formation. The grains of the Cretaceous, Tertiary, and Lower Silurian beds have been shown by Ehrenberg to be the casts of the interior of shells of Rhizopods. The silica has been supposed to come from the siliceous secretions of a minute sponge growing in the cavities that afterwards became occupied by the glauconite.

Celadonite. A green earth with 53 per cent. of silica, from amygdaloid, near Verona. Probably an impure chlorite.

Chloropal. A massive greenish-yellow to pistachio-green compact mineral, somewhat opal-like in appearance, consisting chiefly of silica, iron sesquioxide, and water. *Montronite*, *Pinguite*, *Unghwarite* and *Gramenite* are varieties of it.

Stilpnomelane. Foliated and also fibrous, or as a velvety coating. Black to brownish and yellowish bronze in color and lustre. G.= 8–3·4. Chiefly silica and iron oxides, with 8 to 9 per cent. of water. *Chalcodite* of the Sterling Iron Mine, Antwerp, Jefferson County, N. Y., is here included.

Serpentine.

Usually massive and compact in texture, of a dark oil-green, olive-green, or blackish-green color ; also pale yellowish-green, brownish-yellow and brownish-red. Occurs also fibrous and lamellar. The lamellar varieties consist of thin folia, sometimes separable, but brittle; colors greenish-white, and light to dark green. Often in crystals pseudomorphous after chrysolite, chondrodite, and some other minerals.

Lustre weak; resinous, inclining to greasy. Finer varieties translucent; also opaque. H.=2·5–4. G.=2·5–2·6. Feel sometimes a little unctuous. Tough. Fracture conchoidal.

Composition. A hydrous silicate of magnesium, like talc, but containing much more water and much less silica. $H_2Mg_3O_8Si_2+1$ aq=Silica 43·48, magnesia 43·48, water 13·04=100. B.B. fuses with much difficulty on thin edges. Yields water in the closed tube. Decomposed by hydrochloric acid, leaving a residue of silica. In some kinds the Mg is replaced partly by Fe.

Specimens of a rich oil-green color, and translucent, breaking with a splintery fracture, are sometimes called *precious serpentine,* and the opaque kind, *common* serpentine.

Fibrous serpentine with a silky lustre is called *Chrysotile,* and also *Amianthus.* Unlike asbestus, which it resembles, it affords much water in a closed tube. *Metaxite, Picrolite,* and *Baltimorite* are coarse fibrous kinds. A foliated variety, from Hoboken, N. J., was named *Marmolite,* before it was known to be serpentine. *Antigorite* is a foliated variety. *Williamsite* is similar. *Refdanskite* contains nickel.

A porcelain-like serpentine—the Meerschaum of Taberg and Sala—has been called *Porcellophite;* and a resin-like variety, *Retinalite* and *Vorhauserite.*

Diff. The distinguishing characters are feeble lustre, somewhat resinous, compact structure, little hardness, being so soft as to be easily cut with a knife, and specific gravity not over 2·6.

Obs. Serpentine occurs as a rock, and the several varieties mentioned either constitute the rock or occur in it. Occasionally it is disseminated through granular limestone, giving the latter a clouded green color: this is the *verd antique* marble, called also *Ophiolyte.*

Serpentine occurs in Cornwall; near Portsoy in Aberdeenshire, in Corsica, Siberia, Saxony, Norway at Snarum.

In the United States it occurs at Phillipstown, Port Henry, Gouverneur, Warwick, N. Y.; Newburyport, Westfield, and Blandford, Mass.; at Kellyvale and New Fane, Vt.; Deer Isle, Maine; New Haven, Conn.; Bare Hills, Md.; Hoboken, N. J.; at Brewster's, Putnam County, N. Y., where it occurs pseudomorphous after chondrodite, chlorite, enstatite, biotite, etc.; in Canada at Orford, Ham, Bolton, etc.

Serpentine forms a handsome marble when polished, especially when mixed with limestone, constituting *verd-antique* marble. Its colors are often beautifully clouded, and it is much sought for as a material for tables, jambs for fire-places, and ornamental in-door work. Exposed to the weather, it wears uneven, and soon loses its polish. Chromic iron is usually disseminated through it, and increases the variety of its colors. Near Milford and New Haven, Conn., a handsome verd-antique marble occurs which was formerly worked. A white limestone, dotted and spotted with green serpentine at Port Henry, Essex County, N. Y., is much esteemed for its beauty, and is now extensively worked. The name *serpentine* alludes to the varied green colors of such rocks.

Bowenite from Smithfield, R. I., has the composition of serpentine, but the hardness 5·5–6, and the aspect of nephrite, with G.=2·59–2·8.

Bastite or *Schiller Spar,* is a foliated pyroxene or bronzite altered nearly to serpentine. *Antillite* is similar.

Deweylite.

Massive. Whitish, yellowish, brownish-yellow, greenish, reddish, in color, with the aspect of gum arabic or a resin. Very brittle. H.=2–3·5. G.=1·9–2·25.

In composition near serpentine but containing 20 per cent. of water. From Middlefield, Mass.; Bare Hills, Maryland (*Gymnite*); Texas, Pa., and from the Fleims Valley, Tyrol.

Cerolite. Related to deweylite; from Silesia. *Limbachite* from Limbach, and *Zöblitzite* from Zöblitz, are similar.

Hydrophite. Like deweylite, but containing iron in place of part of the magnesium. From Taberg in Smaoland. *Jenkinsite* is a fibrous variety, occurring on magnetite, at O'Neil's mine in Orange County, N. Y.

Genthite or *Nickel-gymnite*. Similar to deweylite, but containing much nickel and G.=2·4, analysis affording Silica 35·36, nickel protoxide 80·64, iron protoxide 0·24, magnesia 14·60, lime 0·26, water

19·09=100·19. From Texas, Pa.; Webster, N. C.; Michipicoton Island, Lake Superior; Malaga, Spain; Saasthal, Upper Valois. *Röttisite* is similar.

Saponite.

Soft, clay-like, of the consistence before drying of cheese or butter, but brittle when dry. Color white, yellowish, grayish-green, bluish, reddish. Does not adhere to the tongue.

Composition. A hydrous silicate of magnesia containing some alumina.

From Lizard's Point, Cornwall, in serpentine. Also from geodes of datolite, Roaring Brook, Conn.; in trap, north shore of Lake Superior.

Kaolinite.

Trimetric. $I \wedge I = 120°$. Occurs massive, clay-like, but consisting usually of thin, microscopic, rhombic or hexagonal, crystals; either compact, friable, or mealy.

Color white, grayish-white, yellowish, sometimes brownish, bluish, or reddish. Scales transparent or translucent; flexible, inelastic, greasy to the touch. H.=1–2·5. G.=2·4–2·6.

Composition. $H_2Al\,O_8\,Si_2 + 1\,aq$ = Silica 46·4, alumina 39·7, water 13·9=100. The similarity of the composition to that of serpentine will be seen on comparing the two formulas. B.B. infusible. A blue color with cobalt solution. Yields water in the closed tube. Insoluble in acids.

Obs. The soapy feel of kaolinite distinguishes a clay consisting of it from other kinds of clay; and when common clays are "unctuous" it is usually owing to the presence of kaolinite. Kaolinite has been made through the decomposition of aluminous minerals, and especially the potash and soda feldspars, orthoclase, albite, and oligoclase. In the case of these feldspars the process (1) removes the alkalies; (2) leaves the alumina, or a large part of it, and part of the silica; and (3) adds water. So that, with orthoclase, $K_2Al\,O_{16}\,Si_6$ becomes changed to $H_2Al\,O_8\,Si_2 + 1\,aq$; half the water which is added replaces K_2 which is removed. Many granites, gneisses, and other feldspar-bearing rocks undergo rapidly this change, so that extensive beds of kaolinite have been formed and are now making in many regions. The kaolinite is usually washed out by streams or the waves from the decomposed material to make the large pure deposits.

The New Jersey clay-beds of the Cretaceous formation are mainly kaolinite, and have been thus formed. In other cases permeating waters have washed out the oxides of iron present, and have left the white clay in place. A pure kaolinite bed occurs at Brandon, Vermont, along with a limonite bed, where the rock decomposed was probably a feldspathic hydromica slate. Most of the limonite beds of Western New England afford kaolinite; yet it is generally more or less colored by iron oxide.

Common clays consist of finely-powdered feldspar, quartz, and other mineral material, with often more or less kaolinite. They burn red in case they contain iron in the state ordinarily present in them of iron carbonate, or hydrous iron oxide (limonite), or in combination with an organic acid, or in some other alterable state of composition, heat driving off the carbonic acid or water, or destroying the organic acid, and so leaving the red oxide of iron (or sesquioxide), or favoring its production. But the iron may be so combined as not to give the red color; and this has been found to be true with the clays from which the cream-colored Milwaukee (Wisconsin) brick are made, and that of other clay beds in that vicinity. The iron may be there in the state of the silicate, zoisite, or epidote.

Pure kaolinite (or *kaolin* as it is ordinarily called) is used in making the finest porcelain. For this purpose it is mixed with pulverized feldspar and quartz, in the proportion needed to give, on baking, that slight incipient degree of fusion which renders porcelain translucent. The name kaolin is a corruption of the Chinese word *Kauling,* meaning *high ridge,* the name of a hill near Jauchau-Fu, where the mineral is obtained; and the *petuntze* (peh-tun-tsz) of the Chinese, with which the kaolin is mixed in China for the manufacture of porcelain, is, according to S. W. Williams, a quartzose feldspathic rock, consisting largely of quartz. The word porcelain was first given to China-ware by the Portuguese, from its resemblance to certain sea-shells called *Porcellana;* they supposed it to be made from shells, fish-glue, and fish-scales (S. W. Williams).

The impure kaolin is used for stoneware and fire-bricks. The presence of iron, in any state, makes a clay more or less fusible, and therefore an unfit material for fire-bricks. But a little of it exists in all clays employed for making ordinary bricks, and hence their red color.

Pholerite, Halloysite, Smectite, Severite, Glagerite, Lenzinite, Bole, Lithomarge, are names of clay-like minerals.

Pinite.

Amorphous, and usually cryptocrystalline; but often having the form of the crystals of other minerals from the alteration of which it has been made. Colors grayish, greenish, brownish, and sometimes reddish. Lustre feeble; waxy. Translucent to opaque. Acts like a gum on polarized light, and thus indicates the absence of true crystallization, even when under the forms of crystals. H.=2·5–3. G.=2·6–2·85.

Composition. Mostly $(H_3K)_2Al_2O_{20}Si_5$. The pinite of Saxony afforded Silica 46·83, alumina 27·65, iron sesquioxide 8·71, magnesia 1·02, lime 0·49, soda 0·40, potash 6·52, water 3·83 =99·42; and, in another analysis, potash 10·74. The physical characters ally it to serpentine, and also nearly the atomic ratio, and it may be viewed as a potash-alumina serpentine. But at the same time it has very nearly the composition of a hydrous potash mica, or damourite (see next page).

Obs. The varieties are pseudomorphs after different minerals, and hence comes a part of their variations in composition. They include *Pinite,* from the Pini Mine, near Schneeberg and elsewhere; *Gieseckite,* pseudomorph after nephelite from Greenland, and from Diana, N. Y.; *Dysyntribite,* from Diana, identical with gieseckite; *Pinitoid,* from Saxony; *Wilsonite,* from Bathurst, Canada, having the cleavage of scapolite; *Terenite,* from Antwerp, N. Y., like Wilsonite; *Agalmatolite,* or *Pagodite,* from China, being one of the materials for carving into images, ornaments, models of pagodas, etc.; gigantolite and iberite, which have the form of iolite.

Polyargite, Rosite, Cataspilite, Biharite are related materials.

Palagonite. Yellow to brownish yellow, garnet-red to black in color, and resinous to vitreous in lustre. The material of some tufas, and the result of change through the agency of steam or hot water at the time, probably, of the deposition of the material. From tufas of Iceland, Germany, Italy, Sicily, and named from Palagonia, in Sicily.

HYDROMICA GROUP.

The following species are mica-like in cleavage and aspect, but talc-like in wanting elasticity, greasy feel, and pearly lustre. They are sometimes brittle. Common mica, muscovite, readily becomes hydrated on exposure; but hydrous micas are not all a result of alteration. The Hydromica slates form extensive rock-formations, equal to those of the ordinary mica schists. They were for the most part called *Talcose slates* (or *Talk-schiefer* in German) from their greasy feel, until the fact was ascertained that they contained no magnesia: a point demonstrated for the Taconic slates of the western border of Massachusetts, by C. Dewey, in 1819, and later, by G. F. Barker, for those of Vermont. Pinite is related in composition, but is not micaceous.

Margarodite.

Like muscovite (page 267), but inelastic.

Composition. Specimens from the topaz vein, Trumbull, Conn., afforded Silica 46·50, alumina 33·91, iron sesquioxide 2·69, magnesia 0·90, soda 2·70, potash 7·32, water 4·63, fluorine 0·82, chlorine 0·31=99·78. Another from Litchfield, Conn., accompanying cyanite, afforded water 5·26 per cent., soda 4·10, potash 6·20, showing a large percentage of soda. It is probable that both of these micas were *originally* hydrous.

Damourite.

Mica-like, consisting of an aggregation of fine pearly scales, yellow to white in color.

Composition. Near margarodite, being a hydrous potash mica. A specimen from Brittany afforded Silica 45·22, alumina 37·85, potash 11·20, water 5·25=99·52. The quantivalent ratio for the protoxide, sesquioxide, silica, and water is 1:9:12:2, instead of that of margarodite, which is 1:6:9:2. A schistose hydromica slate from Lehigh County, Pennsylvania, afforded Dr. Genth, Silica 49·92, alumina 34·06, iron sesquioxide 0·91, magnesia 1·77, lime 0·11, soda 0·74, potash 6·94, water 6·52=100·97.

Obs. From a locality of cyanite in Brittany, and another in Warmland; also the constituents of a garnetiferous schist at Salm-Château, in Belgium; and in part of extensive schistose formations in Vermont, Western Massachusetts, Western Connecticut, and also just west of New Haven, Connecticut; Eastern Pennsylvania, etc.

For other analyses of hydromica slates, see Dr. Genth's report on the Mineralogy of Pennsylvania; also Geological Report of F. Prime, Jr., for 1874, p. 12.

Parophite. The material of a schist or slate—Parophite Schist—which cuts like massive talc, is of greenish, yellowish, reddish, and grayish colors, and is probably a damourite or hydromica slate, with some free silica (quartz). An analysis afforded Silica 48·46, alumina 27·55, iron protoxide 5·08, magnesia 2·02, lime 2·05, soda 2·35, potash 5·16, water 7·14=99·81. It is from Pownal, Vt., and St. Nicholas, Stanstead, and other neighboring parts of Canada.

Sericite. A damourite-like mineral, with the pearly lustre of talc, and the composition of a hydrous mica; it is the basis of a glossy schist; near Wiesbaden. The scales are described by Rosenbusch as appearing fibrous when highly magnified. Analysis afforded Silica 49·00, alumina 23·65, iron protoxide 8·07, magnesia 0·94, lime 0·63, soda 1·75, potash 9·11, water 3·47, titanic dioxide 1·39, silicon fluoride 1·60=100·14.

Paragonite. A hydrous mica containing *soda* in place of potash. From Mount Campione, in the region of St. Gothard. Color whitish, grayish, yellowish, greenish. Analysis afforded Silica 46·81, alumina 40·06, magnesia 0·65, lime 1·26, soda 6·40, potash *trace*, water 4·82=100. *Pregrattite.* from the Tyrol, afforded soda 7·06, potash 1·71, water 5·04; it exfoliates like the Vermiculites. *Cossaite* is here included.

Groppite. A rose-red to brownish-red foliated mineral from Gropptorp, Sweden.

Euphyllite. Mica-like, with folia rather brittle, pearly lustre, white or colorless. Contains much sodium. An analysis afforded Silica 41·6, alumina 42·3, lime 1·5, potash 3·2, soda 5·9, water 5·5=100. Occurs with corundum at Unionville, Delaware County, Pa.

Œllacherite. Mica-like; strong pearly in lustre, grayish white to white; elastic. Analysis obtained 7·61 potash, 1·42 soda, 4·65 baryta, and 4·43 water, besides silica, alumina, etc.

Cookeite. In minute mica-like scales, and in slender six-sided prisms. Affords only 2·57 of potash, with 2·82 of lithia; the water 13·41 per cent. Occurs on crystals of red tourmaline at Hebron and Paris, Me., and has proceeded from its alteration. Named after Prof. J. P. Cooke, of Cambridge, Mass.

Voigtite is the mica of a granite at Ehrenberg, near Ilmenau, which has the composition of biotite, plus 9 to 10 per cent. of water.

Roscoelite. A vanadium-mica, of dark brownish-green color, occurring in micaceous scales, and affording over 20 per cent. of vanadium oxides, along with 47·69 of silica, 14·10 of alumina, 7·59 of potash, 4·96 of water, and a little magnesia and soda. From Granite Creek Gold Mine, El Dorado County, California.

Fahlunite.

In six and twelve-sided prisms, usually foliated, parallel to the base, but owing its prismatic forms to the mineral from which it was derived. Folia soft and brittle, of a grayish-green to dark olive-green color, and pearly lustre. G. =2·7.

Composition. A hydrous silicate of aluminum and iron with little or no alkali, and in this last point differing from pinite. An average specimen afforded Silica 44·60, alumina 30·10, iron protoxide 3·86, manganese protoxide 2·24, magnesia 6·75, lime 1·35, potash 1·98, water 9·35 = 100·23. B.B. fuses to a white glass. In a closed tube gives water. Insoluble in acids.

Diff. It is distinguished from talc by affording much water before the blowpipe, and readily by its association with iolite, and its large hexagonal forms, with brittle folia.

Obs. Fahlunite has been derived from the alteration of iolite. The quantivalent ratio of iolite for the protoxides, sesquioxides, and silicon is 1:3:5; and for fahlunite, the same, with 1 for the water, making the whole 1:3:5:1. The hydration appears to go on at the ordinary temperature, and in some localities all the iolite to a considerable depth in the rock is changed to fahlunite. There are different varieties, depending on the amount of water, and the conditions under which the change has taken place. The names they have received are *Hydrous Iolite, Chlorophyllite, Esmarkite, Aspasiolite, Pyrargillite, Triclasite. Fahlunite* was so named from its locality, Fahlun, Sweden; and *Chlorophyllite* from its greenish color and foliated structure; the specimens to which it was given occurring at Unity, N. H. Haddam, Ct., is another locality. *Gigantolite, Iberite,* are also altered iolite, but they contain potash, and belong hence to the Pinite Group.

Hisingerite.

Massive; reniform; of a black to brownish-black color, yellowish-brown streak, greasy lustre inclining to vitreous. H. =3. G. =3·045.

Composition. A hydrous iron silicate. Silica 35·9, iron sesquioxide 42·6, water 21·5=100. But in some analyses part of the iron is in the protoxide state. B.B. fuses with difficulty to a magnetic slag.

Obs. From Sweden, Norway, Finland. *Scotiolite* and *Degeröite* are referred to it. *Melanolite,* from Milk-Row quarry, near Charlestown, Mass., is related in composition, if the material analyzed was a pure species.

Approaches in composition the chlorites, and may belong to that group.

Gillingite from Sweden, including *Thraulite* from Bavaria, *Epichlorite*, and *Lillite*, are other hydrous silicates containing iron.

Ekmannite, foliated, chlorite-like, occurs in the rifts of magnetite, in Sweden; it is a hydrous iron silicate, but the iron is mostly in the protoxide state.

Neotocite (*Stratopeite*) and *Wittingite* are results of the alteration of rhodonite, and contain manganese. *Stübelite* also contains manganese oxide.

Strigovite from Striegau, Siberia, and *Jollyte* from Bodenmais in Bavaria, are hydrous silicates of aluminum and iron, with little magnesium.

CHLORITE GROUP.

The chlorite group includes the hydrous *Subsilicates* of the Margarophyllite Section and also some related species that are *Unisilicates*. The proportion of silica is small, the percentage afforded by analyses being under 38, and mostly under 30. The minerals when well crystallized are foliated like the micas, and have the plane angle of the base of the crystals 120°, but the folia are inelastic and in some species brittle. They also occur in fibrous and in fine granular and compact forms, and the latter are usually most common. Green, varying from light to blackish green, is the prevailing color, yet gray, yellowish, reddish, and even white and black also occur; and the colored transparent or translucent are dichroic. The green color is owing to the presence of iron, and fails only in species containing little or none of it. All of the species yield water in a closed tube. The quantivalent (or combining-power) ratio for R+R and Si is, in the

Pyrosclerite subdivision..........$1:1$.
Chlorite subdivision..............$1:\frac{4}{5}$, $1:\frac{3}{4}$, $1:\frac{1}{2}$.
Chloritoid subdivision............$1:\frac{1}{2}$ to $1:\frac{1}{3}$.

The chlorite subdivision includes Penninite, Ripidolite and Prochlorite, together with some related dark-green to blackish-green species. Some species of this subdivision characterize extensive rock formations, making chlorite schist or slate; and they give rise also to chloritic varieties of other rocks. Moreover, chlorite is a result of the alteration of pyroxene, hornblende, and some other iron-bearing minerals; and pyroxenic igneous rocks, like doleryte, are often strongly chloritic (as revealed by the microscopic examination of thin transparent slices), in consequence of this alteration—but alteration that took place before the rock had cooled. Such green chloritic material, where the species is not determinable, has been called *Viridite.* The cavities in amygdaloid are often lined, and sometimes filled, by a species of chlorite, which was made from certain constituents of the amygdaloid in the manner just stated; and the rocks adjoining trap dikes are at times penetrated by chlorite made in them by means of the heat, and the moisture contained in them or ascending with the erupted rock.

Pyrosclerite.

Trimetric or monoclinic. Mica-like in cleavage; folia flexible, not elastic, and pearly in lustre. Color apple-green to emerald-green. H.=3. G.=2·74.

Composition. $(\frac{2}{3}Mg_3\,\frac{1}{3}Al)_2\,O_{12}\,Si_3+3\,aq$=Silica 38·9, alumina 14·8, magnesia 34·6, water 11·7=100. B.B. fuses to a grayish glass; gelatinizes with hydrochloric acid.

Obs. Occurs in serpentine, on Elba.

Chonicrite (_Metaxoite_) is related to the above in composition, but affords 12 to 18 per cent. of lime.

Vermiculite.

Mica-like in cleavage. Grayish, brownish, and yellowish-brown in color. In aggregated scales. Also in large micaceous crystals or plates. Laminæ flexible, not elastic. Lustre pearly.

Composition. $Mg_3\,(Fe,Al)\,O_{12}\,Si_3$. When heated it exfoliates, and when scaly-granular the scales open out into worm-like forms; and thence the name, from the Latin *vermiculor, I breed worms;* B.B. fuses finally to a gray mass. From Milbury, Mass.

Jefferisite is a similar mineral in composition and exfoliation, occurring in broad folia. Composition $\frac{5}{6}Mg_3\,\frac{1}{6}(Fe_2,Al_2)\,O_{12}\,Si_3$. From veins in serpentine in Westchester, Pa. _Culsageeite_ from Culsagee, North

Carolina; *Hallite* from Lerni, Delaware Co., Pa.; *Protovermiculite* from Magnet Cove, Ark., are other micaceous hydrous unisilicates similar to vermiculite and jefferisite in exfoliation. *Kerrite* and *Maconite* are related to the above. They are from Franklin, Macon Co., North Carolina. *Pelhamite* is from Pelham, Mass.

Penninite.—Chlorite in part. Pennine.

Rhombohedral. Cleavage basal and highly perfect, mica-like. Also massive, consisting of an aggregation of scales, and cryptocrystalline.

Color green of various shades; also yellowish to silver-white, and rose-red to violet. Lustre pearly on cleavage surface. Transparent to translucent. Laminæ flexible, not elastic. H.=2–2·5, 3 on edges. G.=2·6–2·85.

Composition. A specimen from Zermatt, in the Pennine Alps, afforded Silica 33·64, alumina 10·64, iron sesquioxide 8·83, magnesia 34·95, water 12·40=100·46. The rose-red, from Texas, Pa., gave Silica 33·20, alumina 11·11, chromium oxide 6·85, iron sesquioxide 1·43, magnesia 35·54, water 12·95, lithia and soda 0·28, potash 0·10=101·46. Other Texas specimens afforded 0·90 to 4·78 per cent. of chromium oxide. B.B. exfoliates somewhat and fuses with difficulty. Partially decomposed by hydrochloric acid, and wholly so by sulphuric acid.

From Zermatt, Ala in Piedmont, the Tyrol, etc. *Kämmererite, Rhodochrome,* and *Rhodophyllite* include the reddish variety from near Miask, Russia; Texas, Pennsylvania; etc. Pseudomorphs after hornblende, named *Loganite,* have the composition of this species; and so has the massive mineral called *Pseudophite* and *Allophite.*

Delessite. A fibrous mineral near the above in composition, from amygdaloid at Oberstein.

Euralite is an amorphous chlorite near Penninite, from Eura, Finland; from amygdaloid.

Diabantite (*Diabantochronyn*) is a chlorite from amygdaloid. A Farmington (Conn.) specimen afforded Hawes, Silica 33·68, alumina 10·84, iron sesquioxide 2·86, iron protoxide 24·33, MnO and CaO 1·11, magnesia 16·52, soda 0·33, water 10·02=99·69.

Chlorophæite is a doubtful species of chlorite, from amygdaloid.

Ripidolite.—Chlorite, in part.

Monoclinic. Similar in cleavage and mica-like character to penninite, and also in its colors, lustre, hardness and specific gravity.

Composition. A specimen from Chester Co., Pennsylvania, afforded Silica 31·34, alumina 17·47, chromium sesquioxide 1·69, iron sesquioxide 3·85, magnesia 33·44, water 12·60=100·39. B.B. and with acids nearly like penninite. A variety from Willimantic, Ct., exfoliates like vermiculite and jefferisite.

Kotschubeite is a red variety from the Urals.

Clinochlore and *Grastite* are here included. Occurs at Achmatovsk and elsewhere in the Urals; at Ala, Piedmont; at Zermatt; at Westchester, Unionville and Texas, Pa.; at Brewster's, N. Y.

Prochlorite.—Chlorite in part.

Hexagonal. Similar in cleavage and mica-like characters to the preceding. Color green to blackish-green; sometimes red across the axis by transmitted light. Laminæ not elastic.

Composition. A specimen from St. Gothard afforded Silica 25·36, alumina 18·56, iron protoxide 28·79, magnesia 17·09, water 8·96=98·70; and a North Carolina specimen, Silica 24·90, alumina 21·77, iron sesquioxide 4·60, iron protoxide 24·21, manganese protoxide 1·15, magnesia 12·78, water 10·59=100. B.B. same as for preceding.

Lophoite, Ogcoite, Helminthe belong here. Occur at St. Gothard, at Greiner in the Tyrol, at Traversella in Piedmont, and many other places in Europe. Also at Steele's Mine, N. C.

Leuchtenbergite is a prochlorite with the base almost solely magnesium.

Aphrosiderite, Metachlorite are near the above in composition.

Venerite is a pale-green earthy chlorite, from a magnetite mine in Berks County, Pa.

Corundophilite is a chlorite near prochlorite in composition. Occurs with corundum at Asheville, N. C.

Grochauite is from Grochau in Silesia.

Cronstedtite. Hexagonal, with perfect basal cleavage. Black. G.=3·35. Consists mainly of silica, iron oxides, and water, with a little manganese oxide. From Bohemia and Cornwall.

Thuringite. Another hydrous iron silicate, having G.=3·15–3·20, from Thuringia, and also Hot Springs, Arkansas, and near Harper's Ferry, on the Potomac. *Pattersonite,* from Unionville, Pa., is near it.

Margarite.—Emerylite. Diphanite. Clingmanite. Corundellite.

Trimetric. Foliated, mica-like. Laminæ rather brittle. Color white, grayish, reddish. Lustre of cleavage surface strong pearly and brilliant, of sides of crystals vitreous. H.=3·5–4·5. G.=2.99.

Composition. $H_2RAl_2O_{12}Si_2$=Silica 30·1, alumina 51.2, lime 11·6, soda 2·6, water 4·5=100. B.B. whitens and fuses on the edges.

Obs. Often associated with corundum and diaspore. Occurs in Asia Minor; at Sterzing in the Tyrol; in the Urals; in Village Green, and Unionville, Pa.; in Buncombe County, N. C.; at Chester, Mass. Named from the Greek *margarites*, a *pearl*.

Willcoxite is near margarite. *Dudleyite* is an alteration product of margarite.

Chloritoid.—Masonite. Phyllite. Ottrelite.

Monoclinic or triclinic. Cleavage basal, perfect. Also coarse foliated massive; and in thin disseminated scales (phyllite or ottrelite). Brittle.

Color dark gray, greenish, to black. Lustre of cleavage surface somewhat pearly.

Composition. $FeAlO_6Si + 1\,aq$=Silica 24·0, alumina 40·5, iron protoxide 28 4, water 7·1=100. B.B. becomes darker and magnetic, but fuses with difficulty. Decomposed completely by sulphuric acid.

Obs. Found at Kossoibrod, Urals, with cyanite; in Asia Minor, with emery; at St. Marcel; Ottrez, France (Ottrelite); Chester, Mass.; in Rhode Island (Masonite); at Brome and Leeds, Canada. Phyllite in scales characterizes the "spangled mica slate" of Newport, R. I., and Sterling, Goshen, etc., Mass.

Seybertite. Occurs in somewhat mica-like, or thin foliated forms, with perfect basal cleavage, and laminæ brittle, the color reddish or yellowish brown to copper-red. Analysis by Brush obtained Silica 20·24, alumina 39·13, iron sesquioxide 3·27, magnesia 20·84, lime 13·69, water 1·04, potash and soda 1·43, zirconia 0·75=100·39, giving the quantivalent ratio for protoxides, sesquioxides, silica, and water 6 : 9 : 5 : ½. From Amity, N. Y.; Slatoust, Urals (*Xanthophyllite*); Fassa Valley (*Brandisite* and *Disterrite*).

IV. HYDROCARBON COMPOUNDS.

The following are the subdivisions here used.

I. SIMPLE HYDROCARBONS: Marsh-gas, Mineral oils, and Mineral wax.

II. OXYGENATED HYDROCARBONS: mostly resins.

III. ASPHALTUM AND MINERAL COALS.

I. SIMPLE HYDROCARBONS.

Marsh-Gas.—Light Carburetted Hydrogen

Colorless and inodorous gas in the pure state. Inflammable, and burns with a yellow flame. Composition $CH_4=$ Carbon 75, hydrogen $25=100$.

Obs. This gas (mixed with more or less carbon dioxide and nitrogen) often rises in bubbles through the waters of marshes, whence its name; and frequently it is discharged from fissures into coal mines in large quantities, constituting the *fire-damp* of the mine. Such natural discharges, called *blowers*, sometimes continue for months. It is the cause of the explosions in mines, a mixture of it with the atmosphere exploding on the approach of the flame of a candle. It destroys life both by the concussion occasioned, by the exhaustion of the atmosphere of oxygen, and by the production of carbon dioxide which takes place. The gas which issues from the oil springs or wells of Western New York (Fredonia), and Eastern Pennsylvania, is marsh-gas mixed with other vapors of the Marsh-gas series. It is used in some places for lighting houses, and even villages; and also for other purposes where heat is required.

The gas bubbling up from a marsh in Europe afforded Websky Carbon dioxide 2·97, marsh-gas 43·36, nitrogen 53·67=100. The first of these ingredients is in fact one of the more abundant results of decomposition, whether vegetable or animal; and the percentage is here small because the gas is soluble in water, and because it readily enters into combinations with the earthy ingredients of plants.

Petroleum.

Mineral oils, varying in density from 0·60 to 0·85. Soluble in benzine or camphene. They consist chiefly of liquids of the Naphtha and Ethylene series. The composition of the Naphtha or Marsh-gas series is expressed by the general formula, $C_nH_{2n}+2$, of which Marsh-gas is the first or lowest term; and that of the Ethylene series by the formula, $C_nH_{2n}=$Carbon 85·71, hydrogen 14·29=100. The oils vary greatly in density from the lightest naphtha, too inflammable for use in lighting, to thick viscid fluids; and thence they pass by insensible gradations into asphaltum or solid bitumen. The Marsh-gas series contains also gases, of the composition C_2H_6 and C_3H_8 and these, in addition to Marsh-gas, often exist in connection with petroleum.

Petroleum occurs in rocks of all ages, from the Lower Silurian to the most recent; in limestones, the more compact sandstones, and shales; but it is mostly obtained from large cavities or caverns existing among the earth's strata. Black shales and much bituminous coal afford it abundantly when they are heated. But the oil obtained is not present in these rocks, for when the rocks are treated with benzine, the benzine takes up little or none; instead, the rocks contain an *insoluble* hydrocarbon, which yields the oil when heat is applied.

In the United States the oil, or the hydrocarbon which yields it, has been observed in beds of the Lower and Upper Silurian, Devonian, Carboniferous, Triassic, Cretaceous, and Tertiary eras. Surface oil springs also occur in many places, as at Cuba, Alleghany County, N. Y., called Seneca Oil Spring; and on a large scale in Santa Barbara, Southern California; at Rangoon in Burmah, where there are about 100 wells; on the peninsula of Apcheron, on the Caspian, and elsewhere. Pliny mentions the oil spring of Agrigentum, Sicily, and says that the liquid was collected and used for burning in lamps, as a substitute for oil. Moreover he distinguishes the oil from the lighter and more combustible naphtha, a locality of which about the sources of the Indus, "in Parthia," he mentions.

Petroleum is obtained chiefly at the present time from more or less deeply-seated subterranean chambers or cavities among the rock strata, reached by boring. Being under pressure of gas associated with it, and also, in many cases, that also of water, it rises to the surface in the boring, and sometimes makes a "spouting" well. As early as 1833, Hildreth mentioned the discharge of oil with the waters of the salt wells of the Little Kanawha valley; and speaks also of a well near Marietta, Ohio, which threw out at one time, he says, 50 to 60 gallons of oil at "each eruption."

The mineral oil of the rocks has been formed through the decomposition of animal and vegetable substances. From the nature of the rocks which most abound in the species of hydrocarbons that yield oil, it is evident that the rock material was in the state of a fine mud; that through this mud much vegetable or animal matter was distributed, almost in the condition of an emulsion; that the stratum of this mud becoming afterward overlaid by other strata, the decomposition of vegetable or animal matter went forward without the presence of atmospheric air, or with only very little of it. Under such circumstances either vegetable material or animal oils might be converted, as chemists have shown, into mineral oil. Dry wood consists approximately (excluding the ash and nitrogen) of 6 atoms of carbon to 9 of hydrogen, and 4 of oxygen. If now all the oxygen of the wood combines with a part of the carbon to form carbonic acid, and this $2\,CO_2$, thus made, is removed, there will be left C_4H_9; twice this, C_8H_{18}, is the formula of a compound of the Marsh-gas or Naphtha series. Again animal oils, by decomposition under similar circumstances, produce like results. Removing from oleic acid its oxygen, O_2, and 1 of carbon—together equivalent to 1 of carbonic acid—there is left $C_{17}H_{34}$, which is an oil of the Ethylene series; and margaric acid would leave, in the same way, $C_{16}H_{34}$, or a combination of oils of the Marsh-gas or Naphtha series. Warren and Storer have obtained from the destructive distillation of a fish-oil, after its saponification by lime, several compounds of the Marsh-gas series, besides others of the Ethylene and Benzole series. The decompositions in nature may not have been as simple as those in the above illustrations, yet the facts warrant the inference that the oils may have been derived either from vegetable or animal matters. Fossil fishes are often found abundantly in black oil-yielding shales, and Dr. Newberry has suggested that fish-oil may be the most abundant source of the oil and the oil-yielding hydrocarbons.

The oil which is collected in great cavities among the earth's strata, as in Western Pennsylvania, is believed, by most writers on the subject to have come from underlying rocks, such as the black oil-yielding shales. The heat produced in the rocks by the friction attending movements and uplifts, is supposed to have been sufficient to have made the oil from the hydrocarbon of the carbonaceous shale or other rock, and to have caused it to ascend among the strata to the cavities where it was condensed, and now is found by boring.

The oils, exposed to the air and wind, undergo change in three ways. *First:* the lighter naphthas evaporate, leaving the denser oils behind; and, ultimately, the viscid bitumens, or else paraffin, according as paraffin is present or not in the native oil. At the naphtha island of Tschelekan in Persia, there are large quantities of *Neft-gil,* as it is called, which is nearly pure paraffin. The hot climate of the Caspian is favorable for such a result. *Secondly:* ther emay be a loss of hydrogen from its combination with the oxygen of the atmosphere to form water, which escapes. Thus the oils of the Naphtha series may change into those of the Ethylene or Benzole series. *Thirdly:* there may be an oxidation of the hydrocarbon of the oils, producing asphaltum or more coal-like substances, like albertite.

The word naphtha is from the Persian, *nafata,* to exude; and petroleum from the Greek, *petros,* rock, and the Latin, *oleum,* oil.

Hachettite.—Mountain Tallow. Hatchetine.

Like soft wax in appearance and hardness, of a yellowish-white to greenish-yellow color.

Composition. Related to paraffin.

From the coal-measures of Glamorganshire in Wales.

Ozocerite is like wax or spermaceti in consistence. Soluble in ether. The original was from Moldavia. Along with another wax-like substance, called *Urpethite,* it constitutes the "mineral wax of Urpeth Colliery." *Zietrisikite* is like beeswax, and is insoluble in ether; from Moldavia.

Elaterite.—Mineral Caoutchouc. Elastic Bitumen.

In soft flexible masses, somewhat resembling caoutchouc or India rubber. Color brownish-black; sometimes orange-red by transmitted light. G. = 0·9–1·25. *Composition:* Carbon 85·5, hydrogen 13·3 = 98·8. It burns readily with a yellow flame and bituminous odor.

Obs. From a lead mine in Derbyshire, England, and a coal mine at Montrelais. It has been found at Woodbury, Ct., in a bituminous limestone.

Fichtelite and *Hartite* are crystallized hydrocarbons, of the Camphene series. *Branchite, Dinite,* and *Ixolyte* are related to Hartite. *Könlite, Naphthalin,* and *Idrialite* are native species of the Benzole series. *Aragotite,* from California, is near Idrialite.

II. OXYGENATED HYDROCARBONS.

Amber.

In irregular masses. Color yellow, sometimes brownish or whitish; lustre resinous. Transparent to translucent. H.=2-2·5. G.=1·18. Electric by friction.

Amber is not a simple resin, but consists mainly (85 to 90 per cent.) of a resin which resists all solvents, called *Succinite*, and two other resins soluble in alcohol and ether, besides an oil, and 2½ to 6 per cent. of *Succinic acid.*

Obs. Occurs in the loose deposits along coasts, especially Tertiary strata, in masses from a very small size to that of a man's head. In the Royal Museum at Berlin, there is a mass weighing 18 pounds. On the Baltic coast it is most abundant, especially between Königsberg and Memel. It is met with at one place in a bed of bituminous coal; it also occurs on the Adriatic; in Poland; on the Sicilian coast near Catania; in France near Paris, in clay; in China. It has been found in the United States, at Gay Head, Martha's Vineyard; Camden, N. J.; and at Cape Sable, near the Magothy River, in Maryland.

It is supposed, with good reason, to be a vegetable resin which has undergone some change while inhumed, a part of which is due to acids of sulphur proceeding from decomposing pyrites or some other source. It often contains insects, and specimens of this kind are so highly prized as frequently to be imitated for the shops. Some of the insects appear evidently to have struggled after being entangled in the then viscous resin, and occasionally a leg or a wing is found some distance from the body, having been detached in the struggle for escape.

Amber is the *elektron* of the Greeks; from its becoming electric so readily when rubbed, it gave the name electricity to science. It was also called *succinum,* from the Greek *succum,* juice, because of its supposed vegetable origin.

It admits of a good polish and is used for ornamental purposes, though not very much esteemed, as it is wanting in hardness and brilliancy of lustre, and moreover is easily imitated. It is much valued in Turkey for mouth-pieces to pipes.

Copalite, or Mineral Copal, *Walchowite, Ambrite* (the New Zealand resin), *Euosmite, Scleretinite, Middletote* are some of the names of other fossil resins; *Geocerite,* and *Geomyricite,* of wax-like oxygenated species; *Guyaquillite, Bathvillite, Torbanite, Ionite* (from Ione valley,

California), of species not resinous in lustre; *Tasmanite* and *Dysodile*, of kinds containing several per cent. of sulphur. *Wollongongite*, from Australia, is black, and looks like cannel coal.

III. ASPHALTUM AND MINERAL COALS.

Asphaltum.

Amorphous and pitch-like. Burning with a bright flame and melting at 90° to 100° F. Soluble mostly or wholly in camphene. It is a mixture of hydrocarbons, part of which are oxygenated.

Obs. Asphaltum is met with abundantly on the shores of the Dead Sea, and in the neighborhood of the Caspian. A remarkable locality occurs on the island of Trinidad, where there is a lake of it about a mile and half in circumference. The bitumen is solid and cold near the shores; but gradually increases in temperature and softness toward the centre, where it is boiling. The appearance of the solidified bitumen is as if the whole surface had boiled up in large bubbles and then suddenly cooled. The ascent to the lake from the sea, a distance of three quarters of a mile, is covered with the hardened pitch, on which trees and vegetation flourish, and here and there, about Point La Braye, the masses of pitch look like black rocks among the foliage. It occurs also in South America about similar lakes in Peru, where it is used for pitching boats; and in California on the coast of Santa Barbara. Large deposits occur in sandstone in Albania. It is also found in Derbyshire, and with quartz and fluor in granite in Cornwall, and at many other places.

Albertite.

Coal-like in hardness, but little soluble in camphene, and only imperfectly fusing when heated; but having the lustre of asphaltum, and softens a little in boiling water. H.=1–2. G.=1·097.

Fills fissures in the Subcarboniferous rocks near Hillsborough, Nova Scotia, and supposed to have been derived from the hydrocarbon of the adjoining rock, and to have been oxidized at the time it was formed and filled the fissure.

Grahamite is a related material from West Virginia, 20 miles south of Parkersburg. H.=2. G.=1·145. Soluble mostly in camphene, but melts only imperfectly. An analysis afforded carbon 76·45, hydrogen 7·82, oxygen (with traces of nitrogen) 13·46, ash 2·26=100.

MINERAL COAL.

Massive. Color black or brown; opaque. Brittle or imperfectly sectile. H.=0·5–2·5. G.=1·2–1·80.

Composition. Carbon, with some oxygen and hydrogen, more or less moisture, and traces also of nitrogen, besides some earthy mineral which constitutes the *ash.* The carbon, or part of it, is in chemical combination with the hydrogen and oxygen.

Coals differ in the amount of volatile ingredients given off when heated. These ingredients are moisture, and hydrocarbon oils and gas, derived from the same class of insoluble hydrocarbons that is the source of the oil of shales and other rocks.

VARIETIES.

1. *Anthracite.* Anthracite (called also *glance coal* and *stone coal*) has a high lustre, and is often iridescent. It is quite compact and hard, and has a specific gravity from 1·3 to 1·75. It usually contains 80 to 93 per cent. of carbon, with 4 to 7 of volatile matter; the rest consisting of earthy impurities. Burns with a feeble blue flame.

Those yielding the most volatile ingredients are called *free-burning* anthracite.

2. *Bituminous Coal.* Bituminous coal varies much in the amount of oil, coal-tar, or gas it yields when heated; and there is a gradual passage in its varieties through *semi-anthracite* to anthracite. It is of a black color, with the powder black, but it is softer than anthracite, and less lustrous. The specific gravity does not exceed 1·5. The volatile ingredients constitute usually between 20 and 40 per cent.

Caking Coal includes that part of bituminous coal which softens when heated and becomes viscid, so that adjoining pieces unite into a solid mass. It burns readily with a lively yellow flame, but requires frequent stirring to prevent its agglutinating, and so clogging the fire. *Non-caking* coal resembles the caking in appearance, but does not soften and cake. The chemical difference between caking and non-caking coal is not understood.

3. *Cannel Coal* is very compact and even in texture, with little lustre, and breaks with a large conchoidal fracture. It takes fire readily, and burns without melting to a clear yel-

low flame, and has hence been used as candles—whence the name. It affords when heated a large amount of mineral oil, and may be used for its production. The volatile ingredients sometimes amount to 50 or 60 per cent. It is often made into inkstands, snuff-boxes, and other similar articles.

4. *Brown Coal* usually has a brownish-black color, and contains 15 to 20 per cent. of oxygen, but much resembles in appearance bituminous coal. The term *brown coal* is applied generally to any coal more recent in origin than the era of the great coal beds of the world. The name *lignite* has sometimes the same general application, though without strict propriety. Lignite is the part of brown coal which has the woody structure still apparent.

Jet resembles cannel coal, but is harder, of a deeper black color, and has a much higher lustre. It receives a brilliant polish, and is set in jewelry. It is the *Gagates* of Dioscorides and Pliny, a name derived from the river Gagas, in Syria, near the mouth of which it was found, and the origin of the term jet now in use.

Native Coke resembles somewhat artificial *coke*, but is more compact, and some varieties of it afford a considerable amount of bitumen. It occurs at the Edgehill mines near Richmond, Virginia, according to Genth, who attributes its origin to the action of a trap eruption on bituminous coal.

It is now well established that mineral coal is mainly of vegetable origin, and that the accumulations out of which the coal beds were made were very similar in character, though not in kinds of plants, to the peat beds of the present day. Peat is vegetation which has undergone, in part, the change to coal; and in some cases it has become *brown coal*. The conditions of change are somewhat different from those of the beds of good coal, since, in the case of the peat, the air has access, while in that of the coal the air was more or less excluded by overlying strata; and the more perfect the exclusion, other things equal, the better the coal. As the composition of mineral coal is closely related to that of mineral oils, the explanation of the origin of the latter, given on page 323, suffices to illustrate also the origin of the former. With a less complete exclusion of the air, oxygenated hydrocarbon compounds, like coal, would be a natural result.

The following are a few analyses of coals, the moisture excluded:

		Carbon.	Hydr.	Oxyg.	Nitr.	Sulph.	Ash.
1	Anthracite, Pennsylvania..	90·45	2·43	2·45	.....	.....	4·67
2	Anthracite, Pennsylvania..	92·59	2·63	1·61	0·92	.....	2 25
3	Anthracite, South Wales...	92·56	3·33	2·53	.....	.....	1·58
4	Caking Coal, Kentucky....	74·45	4·93	13·08	1·03	0·91	5·00
5	Caking Coal, Nelsonville, O.	73·80	5·79	16·58	1·52	0·41	1·90
6	Caking Coal, South Wales..	82·56	5·36	8·22	1·65	0·75	1·46
7	Caking Coal, Northumberl'd	78·69	6·00	10·07	2·37	1·51	1·36
8	Non-caking, Kentucky.....	77·89	5·42	12·57	1·82	3·00	2·00
9	Non-caking "Black Coal," Ind..................	82·70	4·77	9·39	1·62	0·45	1·07
10	Non-caking, Briar Hill, O..	78·94	5·92	11·50	1·58	0·56	1·45
11	Non-caking, S. Staffordshire	76·40	4·62	17·43	.....	0·55	1·55
12	Non-caking, Scotland......	76·08	5·31	13·33	2 09	1·23	1·96
13	Cannel Coal, Breckenridge.	68·13	6·49	5·83	2·27	2·48	12 30
14	Cannel Coal, Wigan.	80·07	5·53	8·10	2·12	1·50	2·70
15	Cannel Coal, "Torbanite".	64·02	8·90	5·66	0 55	0·50	20 32
16	Albertite, Nova Scotia.....	86·04	8·96	1·97	2·93	*trace*	0·10
17	Brown Coal, Bovey........	66·31	5·63	22·86	0·57	2·36	2·27
18	Brown Coal, Wittenberg...	64·07	5·03	27·55	.....	.....	3·35
19	Peat, light brown (imperfect)	50·86	5·80	42·57	0·77	.....	.....
20	Peat, dark brown..........	59·47	6·52	31 51	2 51	.....	.....
21	Peat, black...............	59·70	5·70	33·04	1·56	.....	.....
22	Peat, black...............	59·71	5·27	32·07	2·59	.....	.....

The coal, No. 4, from "Roberts' Seam," Muhlenburg County, Kentucky, has specific gravity=1·26; No. 9, from "Wolf Hill," Daviess County, Indiana, has specific gravity=1·275.

No. 13, the Breckenridge cannel, of Hancock County, Kentucky, consists, when the ash is excluded, of Carbon 82·36, hydrogen 7·84, oxygen 7·05, nitrogen 2·75, and the Bog-head cannel of Scotland, called also *torbanite*, contains Carbon 80·39, hydrogen 11·19, oxygen 7·11, nitrogen 1·31.

The "Mineral Charcoal" of coal beds differs little in composition from ordinary bituminous coal; there is less hydrogen and oxygen. Rowney obtained, for that of Glasgow and Fifeshire, Carbon 82·97, 74·71; hydrogen 3·34, 2·74; oxygen 7·59, 7·67; ash 6·08, 14·86. The nitrogen is included with the oxygen; it was 0·75 in the Glasgow charcoal. Exclusive of the ash, the composition is Carbon 88·36, 87·78; hydrogen 3·56, 3·21; oxygen 7·28, 9·01. It has a fibrous look, and occurs covering the surfaces between layers of coal, and has been observed in coal of all ages. It is soft and soils the fingers like charcoal; one variety of it is a dry powder.

The following are average results, from many analyses:

		Nos.	Sp. gr.	Vol. combust.	Fixed Carbon.	Ash.	Analysis.
1	Pennsylvania anthracites...	7	1·59–1·61	3·92	89·77	6·31	Johnson.
		16	1·39–1·60	5·70	88·23	6·07	Geol. Survey.
2	Pennsylvania semi-anthracites....................	11	1·33–1·45	9·98	82·86	7·16	Geol. Survey.
3	Pennnsylvania semi-bituminous....................	6	1·30–1·41	16·85	72·95	10·20	Johnson.
4	Maryland semi-bituminous...	9	1·30–1·43	15·50	74·03	10·47	Johnson and Geol. Survey.
5	Pennsylvania bituminous....	10	....	28·35	65·18	6·47	Johnson.
6	Virginia bituminous..... ...	11	1·29–1·45	29·88	59·06	11·06	Johnson.
7	Ohio bituminous.............	142	1·24–1·47	35·24	60·26	4·50	Wormley.
8	Indiana bituminous..........	126	1·19–1·41	43·20	53·47	3·33	Cox.
9	Illinois bituminous...........	50	1·21–1·35	31·90	62·44	5·66	Blaney.
10	Iowa bituminous.............	59	....	......	43·02	6·82	Emery.

The ordinary *impurities* of coal, making up its ash, are silica, a little potash and soda, and sometimes alumina, with often oxide of iron, derived usually from sulphide of iron; besides, in the less pure kinds, more or less clay or shale. The amount of ash does not ordinarily exceed 6 per cent., but it is sometimes 30 per cent.; and rarely it is less than 2 per cent. When not over 3 or 4 per cent. the whole may have come from the plants which contributed the most of the material of the coal, since the Lycopods have much alumina in the ash, and the Equiseta much silica.

There is present in most coal traces of sulphide of iron (pyrite), sufficient to give sulphur fumes to the gases from the burning coal, and sometimes enough to make the coal valueless in metallurgical operations. Some thin layers are occasionally full of concretionary pyrite. The sulphur was derived from the plants or from animal life in the waters. Sulphur also occurs, in some coal beds, as a constituent of a resinous substance; and Wormley has shown that part of the sulphur in the Ohio coals is in some analogous state, there being not iron enough present to take the whole into combination.

The average amount of ash in eighty-eight coals from the southern half of Ohio, according to Wormley, is 4·718 per cent.; in sixty-six coals from the northern half, 5·120; in all, from both regions, 4·891; or, omitting ten, having more than ten per cent. of ash, the average is 4·28. In eleven Ohio cannels, the average amount of ash was 12·827. The moisture in the Ohio coals, according to the analyses of Wormley, varies from 1·10 to 9·10 per cent. of the coal.

Mineral coal occurs in extensive beds or layers, interstratified with different rock strata. The associate rocks are usually clay shales (or slaty beds) and sandstones; and the sandstones are occasionally coarse grit rocks or conglomerates. There are sometimes also beds of limestone alternating with the other deposits.

Coal beds vary in thickness from a fraction of an inch to 40 feet. The thickness of a bed may increase or diminish much in the course of a few miles, or the coal may become too shaly to work.

The areas of the "coal-measures" of the Carboniferous era, in the United States, are as follows:

1. A small area in Rhode Island, continued northward into Massachusetts.

2. A large area in Nova Scotia and New Brunswick, stretching eastward and westward from the head of the Bay of Fundy.

These two areas are now separated; but it is probable that they were once united along the region, now submerged, of the Bay of Fundy and Massachusetts Bay.

3. The Alleghany Region, which commences at the north on the southern borders of New York, and stretches southwestward across Pennsylvania, West Virginia, and Tennessee to Alabama, and westward over part of Eastern Ohio, Kentucky, Tennessee, and a small portion of Mississippi. To the north, the Cincinnati "uplift," or the Silurian area extending from Lake Erie over Cincinnati to Tennessee, forms the western boundary.

4. The Michigan coal area, an isolated area wholly confined within the lower peninsula of Michigan.

5. The Eastern Interior area, covering nearly two-thirds of Illinois, and parts of Indiana and Kentucky.

6. The Western Interior area, covering a large part of Missouri, and extending north into Iowa, and South, with interruptions, through Arkansas into Texas, and west into Kansas and Nebraska.

The Illinois and Missouri areas are connected now only through the underlying Subcarboniferous rocks of the age; but it is probable that formerly the coal fields stretched across the channel of the Mississippi, and that the present separation is due to erosion along the valley. Rocks of the Carboniferous period extend over large portions of the Rocky Mountain area, but they are mostly limestones, and are barren of coal.

The extent of the coal-bearing area of these Carboniferous regions is approximately as follows:

Rhode Island area	500 square miles.
Alleghany area	59,000 square miles.
Michigan area	6,700 square miles.
Illinois, Indiana, West Kentucky	47,000 square miles.
Missouri, Iowa, Kansas, Arkansas, Texas	78,000 square miles.
Nova Scotia and New Brunswick	18,000 square miles.

The whole area in the United States is over 190,000 square miles, and in North America about 208,000. Of the 190,000 square miles, perhaps 120,000 have workable beds of coal.

Anthracite is the coal of Rhode Island, and of the areas in Central Pennsylvania, from the Pottsville or Schuylkill coal field to the Lackawanna field, while the coal of Pittsburg, and of all the great coal-fields of the Interior basin, is *bituminous*, excepting a small area in Arkansas. Anthracite belongs especially to regions of upturned rocks, and bituminous coal to those where the beds are little disturbed. In the area between the anthracite region of Central Pennsylvania and the *bituminous* of Western, and farther south, the coal is *semi-bituminous*, as in Broad Top, Pennsylvania, and the Cumberland coal field in Western Maryland, the volatile matters yielded by it being 15 to 20 per cent. The more western parts of the anthracite coal fields afford the free-burning anthracite, or semi-anthracite, as at Trevorton, Shamokin, and Birch Creek.

The coal-formation of the Carboniferous age in Europe has great thickness of rocks and coal in Great Britain, much less in Spain, France, and Germany, and a large surface, with little thickness of coal, in Russia. It exists, also, and includes workable coal-beds, in China, and also in India and Australia; but part of the formation in these latter regions may prove to be Permian. No coal of this era has yet been found in South America, Africa, or Asiatic Russia. The proportion of coal beds to area in different parts of Europe has been stated as follows: in France, 1-100th of the surface; in Spain, 1-50th; in Belgium, 1-20th; in Great Britain, 1-10th. But, while the coal area in Great Britain is about 12,000 square miles, that of Spain is 4,000, that of France about 2,000, and that of Belgium 518.

Mineral coal of later age than the true Carboniferous era occurs in various parts of the world. Triassic or Jurassic coal, of the bituminous variety, occurs in thick workable beds in the vicinity of Richmond, Virginia, and also in the Deep River and Dan River regions in North Carolina; and it constitutes very valuable and extensive beds also in India. In England, at Brora in Sutherlandshire, there is a bed of Jurassic coal. Coal of the Cretaceous and Tertiary eras constitutes important beds in various parts of the Rocky Mountain region, in the vicinity of the Pacific Railroad and elsewhere. Some of the prominent localities are: In Utah, at Evanston and Coalville (in the valley of Weber River), etc.; in Wyoming, at Carbon, 140 miles from Cheyenne; at Hallville, 142 miles farther west; at Black Butte Station, on Bitter Creek; on Bear River, etc.; in the Uintah Basin, near Brush Creek, 6 miles from Green River; in Colorado, at Golden City, 15 miles west of Denver, on Ralston Creek, Coal Creek, S. Boulder Creek and elsewhere; in New Mexico, at the Old Placer Mines in the San Lazaro Mountains, etc. The coal is of the bituminous or semibituminous kind, related to brown coal, and is often improperly called lignite. That of Evanston (where the bed is 26 feet thick) afforded Prof. P. Frazier, Jr., 37–38 per cent. of volatile substances, 5–6 of water, 7–8 of ash, and 49–50 of fixed carbon. At the Old Placer Mines, New Mexico, there is anthracite, according to Dr. J. LeConte, affording 88 to 91 per cent. of fixed carbon; specimens from there, analyzed by Frazier, were semibituminous, affording 68–70 per cent. of fixed carbon, 20 per cent. of volatile substances, and about 3 per cent. of water. The region of the Old Placer Mines is one of upturned and altered rocks, like the anthracite region of Pennsylvania. Other similar beds occur toward the Pacific coast, the most valuable of them in Washington Territory, Seattle and Bellingham Bay, and on Vancouver and adjacent islands in British Columbia.

I. CATALOGUE OF AMERICAN LOCALITIES OF MINERALS.

THE following catalogue of American localities of minerals is introduced as a Supplement to the Descriptions of Minerals. Its object is to aid the mineralogical tourist in selecting his routes and arranging the plan of his journeys. Only important localities, affording cabinet specimens, are in general included; and the *names of those minerals which are obtainable in good specimens are distinguished by italics.* When a name is not italicized the mineral occurs only sparingly or of poor quality. When the specimens to be procured are remarkably good, an exclamation mark (!) is added, or two of those marks (! !) when the specimens are quite unique.

MAINE.

ALBANY.—*Beryl! green and black tourmaline, feldspar, rose quartz,* rutile.

AROOSTOOK.—Red hematite.

AUBURN.—*Lepidolite, hebronite, green tourmaline.*

BATH.—Vesuvianite, *garnet,* magnetite, graphite.

BETHEL.—*Cinnamon garnet,* calcite, sphene, beryl, pyroxene, hornblende, epidote, graphite, talc, pyrite, arsenopyrite, magnetite, wad.

BINGHAM.—*Massive pyrite,* galenite, blende, andalusite.

BLUE HILL BAY.—*Arsenical iron, molybdenite! galenite, apatite! fluorite!* black tourmaline (Long Cove), black oxide of manganese (Osgood's farm), rhodonite, bog manganese, wolframite.

BOWDOIN.—*Rose quartz.*

BOWDOINHAM.—*Beryl,* molybdenite.

BRUNSWICK.—*Green mica, garnet! black tourmaline!* molybdenite, epidote, *calcite, muscovite, feldspar,* beryl.

BUCKFIELD.—*Garnet* (estates of Waterman and Lowe), *muscovite! tourmaline!* magnetite.

CAMDAGE FARM.—(Near the tide mills), molybdenite, wolframite.

CAMDEN.—*Macle, galenite,* epidote, black tourmaline, pyrite, talc, magnetite.

CARMEL (Penobscot Co.)—Stibnite, pyrite, macle.

CORINNA.—*Pyrite, arsenopyrite.*

DEER ISLE.—*Serpentine, verd-antique,* asbestus, diallage.

DEXTER.—Galenite, pyrite, blende, chalcopyrite, green talc.

DIXFIELD.—Native copperas, graphite.

EAST WOODSTOCK.—Muscovite.

FARMINGTON.—(Norton's Ledge), *pyrite,* graphite, garnet, staurolite.

FREEPORT.—*Rose quartz, garnet,* feldspar, scapolite, graphite, *muscovite.*

FRYEBURG.—*Garnet,* beryl.

GEORGETOWN.—(Parker's Island), *beryl!* black tourmaline.

Greenwood.—Graphite, black manganese, *beryl! arsenopyrite*, cassiterite, *mica, rose quartz, garnet*, corundum, albite, zircon, molybdenite, magnetite, copperas.

Hebron.—*Cassiterite*, arsenopyrite, idocrase, *lepidolite, hebronite, rubellite!* indicolite, *green tourmaline, mica, beryl, apatite, albite, childrenite, cookeite.*

Jewell's Island.—Pyrite.

Katahdin Iron Works.—Bog-iron ore, pyrite, magnetite, quartz.

Litchfield.—*Sodalite, cancrinite, elæolite, zircon*, spodumene, muscovite, pyrrhotite.

Lubec Lead Mines.—*Galenite, chalcopyrite, blende.*

Machiasport.—*Jasper*, epidote, laumontite.

Madawaska Settlements.—*Vivianite.*

Minot.—*Beryl, smoky quartz.*

Monmouth.—Actinolite, apatite, *elæolite, zircon*, staurolite, plumose mica, beryl, rutile.

Mt. Abraham.—*Andalusite*, staurolite.

Norway.—*Chrysoberyl!* molybdenite, *beryl, rose quartz, orthoclase*, cinnamon garnet.

Orr's Island.—*Steatite*, garnet, andalusite.

Oxford.—*Garnet, beryl*, apatite, wad, zircon, *muscovite, orthoclase.*

Paris.—*Green! red! black*, and *blue tourmaline! mica! lepidolite!* feldspar, *albite, quartz crystals! rose quartz, cassiterite, amblygonite*, zircon, brookite, beryl, smoky quartz, spodumene, *cookeite*, leucopyrite.

Parsonsfield.—*Vesuvianite! yellow garnet, pargasite, adularia, scapolite*, galenite, blende, chalcopyrite.

Peru.—*Crystallized pyrite.*

Phippsburg.—*Yellow garnet! manganesian garnet, vesuvianite, pargasite, axinite, laumontite!* chabazite, an ore of cerium?

Poland.—Vesuvianite, smoky quartz, cinnamon garnet.

Portland.—*Prehnite*, actinolite, garnet, epidote, amethyst, calcite.

Pownal.—*Black tourmaline, feldspar*, scapolite, pyrite, actinolite, apatite, rose quartz.

Raymond.—*Magnetite, scapolite, pyroxene, lepidolite, tremolite*, hornblende, epidote, orthoclase, yellow garnet, pyrite, vesuvianite.

Rockland.—Hematite, tremolite, *quartz*, wad, *talc.*

Rumford.—*Yellow garnet, vesuvianite, pyroxene*, apatite, scapolite.

Rutland.—Allanite.

Sandy River.—Auriferous sand.

Sanford, York Co.—*Vesuvianite!* albite, calcite, molybdenite, epidote, black tourmaline, labradorite.

Searsmont.—*Andalusite*, tourmaline.

South Berwick.—Macle.

Standish.—*Columbite!*

Streaked Mountain.—*Beryl! black tourmaline, mica, garnet.*

Thomaston.—*Calcite, tremolite, hornblende*, sphene, arsenical iron (Owl's Head), black manganese (Dodge's Mountain), *thomsonite, talc*, blende, pyrite, galenite.

Topsham.—*Quartz*, galenite, blende, tungstite? beryl, apatite, molybdenite, columbite.

Wales.—Axinite in boulder, alum, copperas.

Waterville.—*Crystallized pyrite.*

Windham (near the bridge).—*Staurolite, spodumene, garnet,* beryl, amethyst, *cyanite,* tourmaline.

Winslow.—Cassiterite.

Winthrop.—*Staurolite,* pyrite, hornblende, garnet, copperas.

Woodstock.—*Graphite,* hematite, prehnite, epidote, calcite.

York.—*Beryl,* vivianite, oxide of manganese.

NEW HAMPSHIRE.

Acworth.—*Beryl!! mica! tourmaline, orthoclase, albite, rose quartz, columbite!* cyanite, autunite.

Alstead.—*Mica!! albite, black tourmaline,* molybdenite, andalusite, staurolite.

Amherst.—*Vesuvianite, yellow garnet,* pargasite, calcite, amethyst.

Bartlett.—Magnetite, hematite, *smoky quartz.*

Bath.—Galenite, chalcopyrite.

Bedford.—Tremolite, epidote, graphite, mica, tourmaline, alum, quartz.

Bellows Falls.—Cyanite, staurolite, wavellite.

Bristol.—*Graphite.*

Campton.—*Beryl!*

Canaan.—Gold in pyrite, garnet.

Charleston.—*Staurolite macle, andalusite macle,* bog-iron ore, prehnite, cyanite.

Cornish.—Stibnite, tetrahedrite, *rutile in quartz!* (rare), *staurolite.*

Croyden.—*Iolite!* chalcopyrite, pyrite, pyrrhotite, blende.

Enfield.—Gold, galenite, staurolite, green quartz.

Franceston.—*Soapstone,* arsenopyrite, quartz crystals.

Franconia.—*Hornblende, staurolite! epidote! zoisite, hematite, magnetite, black* and *red manganesian garnets,* arsenopyrite (*danaite*), chalcopyrite, molybdenite, prehnite, green quartz, malachite, azurite.

Gilford (Gunstock Mt.)—Magnetic iron ore, native "lodestone."

Gilmantown.—Tremolite, epidote, muscovite, tourmaline, limonite, red and yellow quartz crystals.

Goshen.—*Graphite,* black tourmaline.

Grafton.—*Mica!* (extensively quarried at Glass Hill, 2 m. S. of Orange Summit), *albite!* blue, green, and yellow *beryls!* (1 m. S. of O. Summit), *tourmaline, garnets, triphylite,* apatite, fluorite.

Grantham.—*Gray staurolite!*

Groton.—Arsenopyrite, blue beryl, muscovite crystals.

Hanover.—*Garnet, black tourmaline, quartz, cyanite, labradorite,* epidote, anorthite.

Haverhill.—*Garnet! arsenopyrite, native arsenic,* galenite, blende, pyrite, chalcopyrite, magnetite, marcasite, steatite.

Hillsboro' (Campbell's Mountain).—*Graphite.*

Hinsdale.—*Rhodonite,* black oxide of manganese, molybdenite, indicolite, black tourmaline.

Jackson.—Drusy quartz, tin ore, *arsenopyrite,* native arsenic, fluorite, apatite, *magnetite, molybdenite,* wolframite, chalcopyrite.

Jaffrey (Monadnock Mt.)—*Cyanite,* limonite.

Keene.—*Graphite,* soapstone, milky quartz, rose quartz.

Landaff.—*Molybdenite,* lead and iron ores.

Lebanon.—*Bog-iron ore,* arsenopyrite, galenite, magnetite, pyrite.

Lisbon.—*Staurolite,* black and red *garnets, magnetite, hornblende, epidote, zoisite,* hematite, arsenopyrite, galenite, gold, ankerite.

Littleton.—Ankerite, gold, bornite, chalcopyrite, malachite, menaccanite, chlorite.

Lyman.—Gold, arsenopyrite, ankerite, dolomite, galenite, pyrite, copper, pyrrhotite.

Lyme.—*Cyanite* (N. W. part), *black tourmaline,* rutile, pyrite, chalcopyrite (E. of E. village), *stibnite,* molybdenite, cassiterite.

Madison.—*Galenite, blende,* chalcopyrite, limonite.

Merrimack.—*Rutile!* (in gneiss nodules in granite vein).

Middletown.—*Rutile.*

Monadnock Mountain.—Andalusite, hornblende, garnet, graphite, tourmaline, orthoclase.

Moosilauke Mt.—*Tourmaline.*

Moultonborough (Red Hill).—*Hornblende,* bog ore, pyrite, tourmaline.

Newington.—Garnet, tourmaline.

New London.—Beryl, *molybdenite,* muscovite crystals.

Newport.—Molybdenite.

Orange.—*Blue beryls!* Orange Summit, chrysoberyl, *mica* (W. side of mountain), apatite, galenite, limonite.

Orford.—*Brown tourmaline* (now obtained with difficulty), *steatite, rutile,* cyanite, brown iron ore, native copper, malachite, galenite, garnet, graphite, molybdenite, pyrrhotite, melaconite, chalcocite, *ripidolite.*

Pelham.—*Steatite.*

Piermont.—*Micaceous iron,* barite, green, white, and brown mica, apatite, titanic iron.

Plymouth.—Columbite, beryl.

Richmond.—*Iolite!* rutile, steatite, pyrite, anthophyllite, talc.

Rye.—Chiastolite.

Saddleback Mt.—Black tourmaline, garnet, spinel.

Shelburne.—*Galenite, black blende, chalcopyrite, pyrite,* pyrolusite.

Springfield.—Beryls (very large, eight inches diameter), *manganesian garnets! black tourmaline!* in mica slate, *albite, mica.*

Sullivan.—*Tourmaline* (black) in quartz, beryl.

Surrey.—Amethyst, calcite, galenite, limonite, tourmaline.

Tamworth (near White Pond).—Galenite.

Unity (estate of James Neal).—*Copper and iron pyrites, chlorophyllite, green mica, radiated actinolite,* garnet, *titaniferous iron ore, magnetite,* tourmaline.

Walpole (near Bellows Falls).—Macle, staurolite, mica, graphite.

Ware.—Graphite.

Warren.—*Chalcopyrite, blende, epidote,* quartz, *pyrite, tremolite, galenite, rutile, talc,* molybdenite, *cinnamon stone! pyroxene,* hornblende, *beryl,* cyanite, tourmaline (massive) vesuvianite.

Waterville.—Labradorite, chrysolite.

Westmoreland (south part).—*Molybdenite! apatite! blue feldspar, bog manganese* (north village), quartz, *fluorite,* chalcopyrite, molybdite.

White Mts. (Notch near the "Crawford House").—Green octahedral fluorite, quartz crystals, black tourmaline, chiastolite, beryl, calcite, amethyst, amazon-stone.

Wilmot.—*Beryl.*

Winchester.—Pyrolusite, rhodonite, rhodochrosite, psilomelane, magnetite, granular quartz, spodumene.

VERMONT.

Addison.—*Iron sand,* pyrite.

Athens.—*Steatite, rhomb spar,* actinolite, garnet.

Baltimore.—*Serpentine, pyrite!*

Belvidere.—Steatite, chlorite.

Bennington.—*Pyrolusite,* brown iron ore, pipe clay, yellow ochre.

Berkshire.—*Epidote,* hematite, magnetite.

Bethel.—*Actinolite!* talc, chlorite, octahedral iron, *rutile, brown spar in steatite.*

Brandon.—Braunite, pyrolusite, *psilomelane,* limonite, lignite, kaolinite, statuary marble; graphite, chalcopyrite.

Brattleborough.—Black tourmaline in quartz, mica, zoisite, rutile, actinolite, scapolite, spodumene, roofing slate.

Bridgewater.—*Talc, dolomite, magnetite,* steatite, chlorite, gold, native copper, blende, galenite, blue spinel, chalcopyrite.

Bristol.—*Rutile,* limonite, manganese ores, magnetite.

Brookfield.—Arsenopyrite, *pyrite.*

Cabot.—Garnet, staurolite, hornblende, *albite.*

Castleton.—*Roofing slate,* jasper, manganese ores, chlorite.

Cavendish.—Garnet, *serpentine, talc, steatite, tourmaline, asbestus, tremolite.*

Chester.—*Asbestus,* feldspar, chlorite, *quartz.*

Chittenden.—Psilomelane, pyrolusite, brown iron ore, *hematite* and *magnetite,* galenite, iolite.

Colchester.—Brown iron ore, iron sand, jasper, alum.

Corinth.—Chalcopyrite (has been mined), pyrrhotite, pyrite, rutile.

Coventry.—Rhodonite.

Craftsbury.—Mica in concentric balls, calcite, rutile.

Derby.—Mica (*adamsite*).

Dummerston.—Rutile, roofing slate.

Fair Haven.—*Roofing slate,* pyrite.

Fletcher.—Pyrite, magnetite, acicular tourmaline.

Grafton.—The *steatite* quarry referred to Grafton is properly in Athens; *quartz,* actinolite.

Guilford.—Scapolite, rutile, roofing slate.

Hartford.—Calcite, *pyrite! cyanite,* quartz, tourmaline.

Irasburgh.—Rhodonite, *psilomelane.*

Jay.—*Chromite, serpentine,* amianthus, dolomite.

Lowell.—Picrosmine, amianthus, serpentine, talc, chlorite.

Marlboro'.—*Rhomb spar, steatite, garnet, magnetite,* chlorite.

Middlebury.—Zircon.

Middlesex.—Rutile ! (exhausted).

Monktown.—*Pyrolusite,* brown iron ore, pipe clay, feldspar.

Moretown.—*Smoky quartz! steatite,* talc, wad, rutile, serpentine.

Morristown.—Galenite.

Mount Holly.—*Asbestus,* chlorite.

New Fane.—*Glassy* and *asbestiform actinolite, steatite, green quartz* (called chrysoprase at the locality), chalcedony, drusy quartz, *garnet, chromic and titanic iron, rhomb spar*, serpentine, rutile.

Norwich.—*Actinolite, feldspar, brown spar*, in talc, cyanite, zoisite, chalcopyrite, pyrite.

Pittsford.—*Brown iron ore*, manganese ores, *statuary marble!*

Plymouth.—Siderite, magnetite hematite, *gold*, galenite.

Plympton.—Massive hornblende.

Putney.—Fluorite, *limonite, rutile*, and *zoisite*, in boulders, staurolite.

Reading.—*Glassy actinolite* in talc.

Readsboro'.—*Glassy actinolite, steatite*, hematite.

Ripton.—*Brown iron ore*, augite in boulders, octahedral pyrite.

Rochester.—Rutile, hematite cryst., *magnetite* in chlorite slate.

Rockingham (Bellows Falls).—Cyanite, indicolite, feldspar, tourmaline, fluorite, calcite, prehnite, staurolite.

Roxbury.—*Dolomite, talc*, serpentine, asbestus, quartz.

Rutland.—*Magnesite, white marble*, hematite, serpentine, pipe clay.

Salisbury.—Brown iron ore.

Sharon.—*Quartz crystals*, cyanite.

Shoreham.—*Pyrite*, black marble, calcite.

Shrewsbury.—Magnetite and chalcopyrite.

Stirling.—Chalcopyrite, talc, serpentine.

Stockbridge.—Arsenopyrite, magnetite.

Strafford.—Magnetite and *chalcopyrite* (has been worked), native copper, hornblende, copperas.

Thetford.—Blende, *galenite, cyanite*, chrysolite in basalt, pyrrhotite, *feldspar, roofing slate*, steatite, garnet.

Townshend.—*Actinolite*, black mica, *talc*, steatite, feldspar.

Troy.—*Magnetite*, talc, serpentine, picrosmine, amianthus, *steatite*, one mile southeast of village of South Troy, on the farm of Mr. Pierce, east side of Missisco, chromite, zaratite.

Vershire.—*Pyrite*, chalcopyrite, tourmaline, arsenopyrite, quartz.

Wardsboro'.—*Zoisite*, tourmaline, *tremolite*, hematite.

Warren.—Actinolite, magnetite, wad, serpentine.

Waterbury.—Arsenopyrite, chalcopyrite, *rutile, quartz*, serpentine.

Waterville.—*Steatite*, actinolite, talc.

Weathersfield.—*Steatite*, hematite, *pyrite*, tremolite.

Wells' River.—Graphite.

Westfield.—*Steatite*, chromite, serpentine.

Westminster.—Zoisite in boulders.

Windham.—*Glassy actinolite, steatite, garnet*, serpentine.

Woodbury.—Massive pyrite.

Woodstock.—*Quartz crystals*, garnet, zoisite.

MASSACHUSETTS.

Alford.—Galenite, pyrite.

Athol.—*Allanite*, fibrolite (?), *epidote!* babingtonite?

Auburn.—*Masonite.*

Barre.—*Rutile! mica, pyrite, beryl, feldspar, garnet.*

Great Barrington.—*Tremolite.*

Bedford.—*Garnet.*

Belcherton.—Allanite.

Bernardston.—Magnetite.

Beverly.—Columbite, *green feldspar*, cassiterite.

Blanford.—*Serpentine, anthophyllite, actinolite! chromite*, cyanite, rose quartz in boulders.

Bolton.—*Scapolite! petalite, sphene, pyroxene, nuttalite, diopside, boltonite*, apatite, magnesite, rhomb spar, *allanite, yttrocerite!* spinel.

Boxborough.—*Scapolite*, spinel, *garnet*, augite, actinolite, apatite.

Brighton.—Asbestus.

Brimfield (road leading to Warren).—*Iolite*, adularia, molybdenite, mica, garnet.

Carlisle.—*Tourmaline, garnet! scapolite*, actinolite.

Charlestown.—*Prehnite, laumontite*, stilbite, chabazite, quartz crystals, melanolite.

Chelmsford.—*Scapolite* (chelmsfordite), *chondrodite, blue spinel, amianthus!* rose quartz.

Chester.—*Hornblende, scapolite, zoisite, spodumene, indicolite*, apatite, magnetite, chromite, stilbite, heulandite, analcite and chabazite. At the Emery Mine, Chester Factories.—*Corundum, margarite, diaspore*, epidote, corundophilite, chloritoid, tourmaline, *menaccanite!* rutile, biotite, indianite? andesite? *cyanite*, amesite.

Chesterfield.—*Blue, green, and red tourmaline, cleavelandite* (albite), lepidolite, *smoky quartz, microlite, spodumene, cyanite*, apatite, *rose beryl, garnet, quartz crystals, staurolite*, cassiterite, *columbite*, zoisite, uranite, brookite (eumanite), scheelite, anthophyllite, bornite.

Conway.—Pyrolusite, fluorite, zoisite, *rutile!!* native alum, galenite.

Cummington.—*Rhodonite!* cummingtonite (hornblende), marcasite, *garnet*.

Deerfield.—Chabazite, heulandite, stilbite, amethyst, carnelian, chalcedony, *agate*.

Fitchburg (Pearl Hill).—*Beryl, staurolite!* garnets, molybdenite.

Foxborough.—*Pyrite, anthracite*.

Franklin.—Amethyst.

Goshen.—*Mica, albite, spodumene! blue and green tourmaline, beryl, zoisite*, smoky quartz, columbite, tin ore, galenite, beryl (goshenite), cymatolite.

Greenfield (in sandstone quarry, half mile east of village).—Allophane, white and greenish.

Hatfield.—Barite, galenite, blende, chalcopyrite.

Hawley.—*Micaceous iron*, massive pyrite, magnetite, zoisite.

Heath.—*Pyrite, zoisite*.

Hinsdale.—Brown iron ore, apatite, zoisite.

Hubbardston.—*Massive pyrite*.

Huntington (name changed from Norwich).—*Apatite! black tourmaline, beryl, spodumene! triphylite* (altered), blende, quartz crystals, cassiterite.

Lancaster.—*Cyanite, chiastolite!* apatite, staurolite, pinite, andalusite.

Lee.—*Tremolite! sphene!* (east part).

Leverett.—Barite, galenite, blende, chalcopyrite.

Leyden.—*Zoisite, rutile*.

Littlefield.—Spinel, scapolite, apatite.

Lynnfield.—Magnesite on serpentine.

Mendon.—*Mica!* chlorite.

Middlefield.—*Glassy actinolite, rhomb spar, steatite, serpentine, feldspar,* drusy quartz, apatite, zoisite, nacrite, chalcedony, *talc!* deweylite.

Milbury.—*Vermiculite.*

New Braintree.—*Black tourmaline.*

Newbury.—*Serpentine,* chrysotile, *epidote, massive garnet,* siderite.

Newburyport.—*Serpentine, nemalite,* uranite.—Argentiferous galenite, tetrahedrite, chalcopyrite, pyrargyrite, etc.

Northfield.—*Columbite,* fibrolite, cyanite.

Norwich.—See Huntington.

Palmer (Three Rivers).—*Feldspar,* calcite.

Pelham.—*Asbestus,* serpentine, *quartz crystals,* beryl, *molybdenite, green hornstone,* epidote, amethyst, corundum, vermiculite (pelhamite).

Plainfield.—*Cummingtonite, pyrolusite, rhodonite.*

Richmond.—*Brown iron ore, gibbsite! allophane.*

Rockport.—*Danalite, cryophyllite, annite, cyrtolite* (altered zircon), *green* and *white orthoclase,* fergusonite.

Rowe.—Epidote, talc.

South Royalston.—*Beryl!!* (now obtained with great difficulty), *mica!! feldspar!* allanite. Four miles beyond old loc., on farm of Solomon Heywood, *mica! beryl! feldspar!* menaccanite.

Russel.—Schiller spar (diallage?), *mica,* serpentine, beryl, galenite, chalcopyrite.

Salem.—In a boulder, cancrinite, sodalite, elæolite.

Sheffield.—*Asbestus,* pyrite, native alum, pyrolusite, rutile.

Shelburne.—Rutile.

Shutesbury (east of Locke's Pond).—*Molybdenite.*

Southampton.—*Galenite,* cerussite, anglesite, *wulfenite,* fluorite, barite, pyrite, chalcopyrite, blende, phosgenite, pyromorphite, stolzite, chrysocolla.

Sterling.—*Spodumene, chiastolite,* siderite, arsenopyrite, *blende,* galenite, chalcopyrite, pyrite, sterlingite (damourite).

Stoneham.—*Nephrite.*

Sturbridge.—*Graphite,* garnet, apatite, bog ore.

Swampscot.—*Orthite,* feldspar.

Taunton (one mile south).—Paracolumbite (titanic iron).

Turner's Falls (Conn. River).—Chalcopyrite, prehnite, chlorite, siderite, malachite.

Tyringham.—Pyroxene, scapolite.

Uxbridge.—Galenite.

Warwick.—*Massive garnet, radiated black tourmaline, magnetite,* beryl, epidote.

Washington.—*Graphite.*

Westfield.—*Schiller spar* (diallage), *serpentine, steatite,* cyanite, scapolite, actinolite.

Westford.—*Andalusite!*

West Hampton.—Galenite, *argentine, pseudomorphous quartz.*

West Springfield.—*Prehnite,* ankerite, satin spar, celestite.

West Stockbridge.—*Limonite,* fibrous pyrolusite, siderite.

Whately.—*Native copper,* galenite.

Williamsburg.—*Zoisite,* pseudomorphous quartz, apatite, rose and smoky quartz, galenite, pyrolusite, chalcopyrite.

Williamstown.—*Cryst. quartz.*

Windsor.—*Zoisite,* actinolite, *rutile!*

Worcester.—Arsenopyrite, idocrase, pyroxene, garnet, amianthus, bucholzite, siderite, galenite.

Worthington.—*Cyanite.*

Zoar.—Bitter spar, *talc.*

RHODE ISLAND.

Bristol.—*Amethyst.*

Coventry.—Mica, tourmaline.

Cranston.—Actinolite in talc, graphite, cyanite, mica, melanterite.

Cumberland.—*Manganese, epidote, actinolite,* garnet, titaniferous iron, magnetite, red hematite, chalcopyrite, bornite, malachite, azurite, calcite, apatite, feldspar, zoisite, mica, quartz crystals, ilvaite.

Diamond Hill.—Quartz crystals, hematite.

Foster.—*Cyanite,* hematite.

Gloucester.—*Magnetite* in chlorite slate, feldspar.

Johnston.—Talc, brown spar, calcite, garnet, epidote, pyrite, hematite, magnetite, chalcopyrite, malachite, azurite.

Natic.—See Warwick.

Newport.—*Serpentine,* quartz crystals.

Portsmouth.—*Anthracite,* graphite, asbestus, pyrite, chalcopyrite.

Smithfield.—*Dolomite, calcite, bitter spar, siderite, nacrite,* serpentine (bowenite), tremolite, asbestus, quartz, magnetic iron in chlorite slate, *talc!* octahedrite, feldspar, beryl.

Valley Falls.—Graphite, pyrite, hematite.

Warwick (Natic village).—*Masonite,* garnet, graphite.

Westerly.—Menaccanite.

Woonsocket.—Cyanite.

CONNECTICUT

Berlin.—Barite, datolite, blende, quartz crystals.

Bolton.—Staurolite, chalcopyrite.

Bradleyville (Litchfield).—Laumontite.

Bristol.—*Chalcocite, chalcopyrite,* barite, *bornite, allophane,* pyromorphite, *calcite,* malachite, galenite, quartz.

Brookfield.—Galenite, calamine, *blende,* spodumene, pyrrhotite.

Canaan.—*Tremolite* and white *augite!* in dolomite, canaanite (massive pyroxene).

Chatham.—Arsenopyrite, smaltite, cloanthite (chathamite), scorodite, niccolite, *beryl,* erythrite.

Cheshire.—*Barite! chalcocite, bornite, malachite,* kaolin, natrolite, prehnite, chabazite, datolite.

Chester.—*Sillimanite!* zircon, epidote.

Cornwall.—*Graphite, pyroxene, actinolite, sphene,* scapolite.

Danbury.—*Danburite, oligoclase, moonstone,* brown tourmaline, orthoclase, pyroxene, parathorite.

Farmington.—*Prehnite, chabazite,* agate, native copper; in trap, *diabantite.*

Granby.—Green malachite.

Greenwich.—*Black tourmaline.*

Haddam.—*Chrysoberyl! beryl! epidote! tourmaline! feldspar, garnet! iolite! oligoclase, chlorophyllite! automolite, magnetite, adularia,* apatite, *columbite!* (hermannolite), zircon (calyptolite), *mica,* pyrite, marcasite, *molybdenite,* allanite, bismuth ochre, bismutite.

Hadlyme.—Chabazite and stilbite in gneiss with epidote and garnet.

Hartford.—*Datolite* (Rocky Hill quarry).

Kent.—*Limonite,* pyrolusite.

Litchfield.—*Cyanite* with corundum, apatite, and andalusite, *menaccanite* (washingtonite), chalcopyrite, diaspore, niccoliferous pyrrhotite, margarodite.

Lyme.—Garnet, sunstone.

Middlefield Falls.—Datolite, chlorite, etc., in amygdaloid.

Middletown.—*Mica, lepidolite* with green and red tourmaline, *albite, feldspar, columbite! prehnite, garnet* (sometimes octahedral), beryl, topaz, uranite, apatite, pitchblende ; at lead mine, *galenite, chalcopyrite,* blende, quartz, *calcite,* fluorite, pyrite sometimes capillary.

Milford.—Sahlite, *pyroxene, asbestus,* zoisite, verd-antique, marble, pyrite.

New Britain.—Agate, *diabantite,* barite, datolite, prehnite, calcite, dolomite.

New Haven.—Serpentine, sahlite, stilbite, prehnite, chabazite, laumontite, gmelinite, apophyllite, topazolite.

Newtown.—*Cyanite, diaspore, rutile,* damourite, cinnabar.

Norwich.—*Sillimanite, monazite! iolite,* corundum, feldspar.

Oxford (near Humphreysville).—Cyanite, chalcopyrite.

Portland.—Orthoclase, *albite, muscovite, biotite, beryl,* tourmaline, columbite, apatite.

Plymouth.—Galenite, *heulandite, fluorite, chloryphyllite!* garnet.

Redding (near the line of Danbury).—Pyroxene, *garnet.* Near Branchville R. R. depot: *Albite, microcline,* hebronite, *spodumene! cymatolite, damourite,* eosphorite, triploidite, reddingite, dickinsonite, lithiophilite, *rhodochrosite,* fairfieldite, *apatite,* microlite, *columbite,* garnet, pyrite, tourmaline, staurolite, uraninite, torbernite, autunite, vivianite, triphylite.

Roaring Brook (Cheshire).—*Datolite!* calcite, prehnite, saponite.

Roxbury.—*Siderite, blende, pyrite!! galenite,* quartz, chalcopyrite, arsenopyrite, limonite.

Salisbury.—Limonite, *pyrolusite,* triplite, *turgite.*

Saybrook.—*Molybdenite,* stilbite, plumbago.

Seymour.—Native bismuth, arsenopyrite, pyrite.

Simsbury.—*Copper glance,* green malachite.

Southbury.—Rose quartz, laumontite, prehnite, calcite, barite.

Southington.—Barite, datolite, asteriated quartz crystals.

Stafford.—Massive pyrites, alum, copperas.

Stonington.—Stilbite and *chabazite* on gneiss.

Tariffville.—*Datolite.*

Tolland.—Staurolite, massive pyrites.

Trumbull and Monroe.—*Chlorophane, topaz, beryl,* diaspore, pyrrhotite, pyrite, niccolite, scheelite, *wolframite* (pseudomorph of scheelite), rutile, native bismuth, tungstic acid, siderite, arsenopyrite, argentiferous galenite, blende, scapolite, *tourmaline, garnet,* albite, augite, graphic tellurium (?), *margarodite.*

Washington.—*Tripolite, menaccanite!* (washingtonite of Shepard), rhodochrosite, natrolite, *andalusite* (New Preston), cyanite.

Watertown, near the Naugatuck.—White sahlite, monazite.

West Farms.—Asbestus.

Willimantic.—*Topaz, monazite, ripidolite.*

Winchester and Wilton.—Asbestus, garnet.

NEW YORK.

ALBANY CO.—Bethlehem.—Calcite, stalactite, stalagmite, calcareous sinter, snowy gypsum.

Coeyman's Landing.—Gypsum, epsom salt, *quartz* crystals at Crystal Hill, three miles south of Albany.

Guilderland.—Petroleum, anthracite, and calcite, on the banks of Norman's Kill, two miles south of Albany.

Watervliet.—*Quartz crystals,* yellow drusy quartz.

ALLEGHANY CO.—Cuba.—Calcareous tufa, petroleum, 8½ miles from the village.

CATTARAUGUS CO.—Freedom.—*Petroleum.*

CAYUGA CO.—Auburn.—Celestite, calcite, fluor spar, epsomite.

Springport.—At Thompson's plaster beds, *sulphur! selenite.*

Springville.—Nitrogen springs.

Union Springs.—*Selenite,* gypsum.

CHATAUQUE CO.—Fredonia.—*Petroleum, carburetted hydrogen.*

Laona.—Petroleum.

CLINTON CO.—Arnold Iron Mine.—*Magnetite,* epidote, molybdenite.

Finch Ore Bed.—*Calcite, green* and purple fluor.

COLUMBIA CO.—Austerlitz.—*Earthy manganese,* wulfenite, chalcocite; Livingston lead mine, galenite.

Chatham.—Quartz, pyrite in cubic crystals in slate (Hillsdale).

Canaan.—Chalcocite, chalcopyrite.

Hudson.—Epidote, *selenite!*

New Lebanon.—Nitrogen springs, graphite, anthracite; at the Ancram lead mine, galenite, barite, *blende, wulfenite* (rare), chalcopyrite, calcareous tufa; near the city of Hudson, epsom salt, brown spar, *wad.*

DUTCHESS CO.—Amenia.—Dolomite, *limonite, turgite.*

Beekman.—*Dolomite.*

Dover.—Dolomite, tremolite, *garnet* (Foss ore bed), staurolite, *limonite.*

Fishkill.—Dolomite; near Peckville, talc, asbestus, *graphite, hornblende,* augite, *actinolite,* hydrous anthophyllite, *limonite.*

North East.—Chalcocite, chalcopyrite, galenite, blende.

Rhinebeck.—Calcite, green feldspar, epidote, tourmaline.

Union Vale.—At the Clove mine, *gibbsite, limonite.*

ESSEX CO.—Alexandria.—Kirby's graphite mine, *graphite, pyroxene, scapolite,* sphene.

Crown Point.—*Apatite* (eupyrchroite of *Emmons*), *brown tourmaline!* in the apatite, chlorite, quartz crystals, pink and blue calcite, pyrite; a short distance south of J. C. Hammond's house, *garnet, scapolite*, chalcopyrite, *aventurine feldspar*, zircon, magnetic iron (Peru), epidote, mica.

KEENE.—Scapolite.

LEWIS.—*Tabular spar, colophonite*, garnet, *labradorite, hornblende*, actinolite; ten miles south of the village of Keeseville, arsenopyrite.

LONG POND.—Apatite, *garnet, pyroxene*, idocrase, *coccolite!! scapolite*, magnetite, *blue calcite*.

MCINTYRE.—*Labradorite*, garnet, *magnetite*.

MORIAH, at Sandford Ore Bed.—*Magnetite*, apatite, *allanite!* lanthanite, actinolite, and feldspar; at Fisher Ore Bed, *magnetite*, feldspar, quartz; at Hall Ore Bed, or "New Ore Bed," *magnetite, zircons;* on Mill brook, *calcite*, pyroxene, hornblende, albite; in the town of Moriah, magnetite, *black mica;* Barton Hill Ore Bed, *albite*.

NEWCOMB.—*Labradorite*, feldspar, magnetite, hypersthene.

PORT HENRY.—*Brown tourmaline, mica, rose quartz, serpentine, green* and *black pyroxene*, hornblende, *cryst. pyrite*, graphite, wollastonite, pyrrhotite, *adularia; phlogopite!* at Cheever Ore Bed, with magnetite and serpentine.

ROGER'S ROCK.—*Graphite, wollastonite, garnet, collophonite, feldspar*, adularia, *pyroxene, sphene*, coccolite.

SCHROON.—*Calcite*, pyroxene, *chondrodite*.

TICONDEROGA.—*Graphite! pyroxene, sahlite, sphene*, black tourmaline, cacoxene? (Mt. Defiance).

WESTPORT.—Labradorite, prehnite, magnetite.

WILLSBORO'.—*Wollastonite, colophonite*, garnet, *green coccolite*, hornblende.

ERIE CO.—ELLICOTT'S MILLS.—*Calcareous tufas*.

FRANKLIN CO.—CHATEAUGAY.—Nitrogen springs, calcareous tufas.

MALONE.—*Massive pyrite*, magnetite.

GENESEE CO.—*Acid springs* containing sulphuric acid.

GREENE CO.—CATSKILL.—*Calcite*.

DIAMOND HILL.—Quartz crystals.

HAMILTON CO.—LONG LAKE.—Blue calcite.

HERKIMER CO.—FAIRFIELD.—*Quartz crystals*, fetid barite.

LITTLE FALLS.—*Quartz crystals!* barite, calcite, anthracite, pearl spar, *smoky quartz;* one mile south of Little Falls, calcite, brown spar, feldspar.

MIDDLEVILLE.—*Quartz crystals! calcite*, brown and pearl spar, anthracite.

NEWPORT.—*Quartz crystals*.

SALISBURY.—*Quartz crystals!* blende, galenite, pyrite, chalcopyrite.

STARK.—Fibrous celestite, *gypsum*.

JEFFERSON CO.—ADAMS.—Fluor, calc tufa, barite.

ALEXANDRIA.—On the S. E. bank of Muscolonge Lake, fluorite (exhausted), *phlogopite*, chalcopyrite, apatite; on High Island, in the St. Lawrence River, feldspar, *tourmaline*, hornblende, *orthoclase*, celestite.

ANTWERP.—Sterling iron mine, hematite, *chalcodite*, siderite, *millerite, red hematite*, crystallized quartz, *yellow aragonite*, niccoliferous pyrite, *quartz crystals*, pyrite; at Oxbow, *calcite!* porous coralloidal heavy spar; near Vrooman's lake, *calcite!* vesuvianite, *phlogopite! pyroxene, sphene*, fluorite, pyrite, chalcopyrite; also *feldspar, bog-iron* *ore*, scapolite (farm of Eggleson), *serpentine*, tourmaline (yellow, rare).

Brownsville.—Celestite in slender crystals, calcite (four miles from Watertown).

Natural Bridge.—*Gieseckite! steatite pseudomorphous* after pyroxene, apatite.

New Connecticut.—*Sphene, brown phlogopite.*

Omar.—*Beryl, feldspar,* hematite.

Philadelphia.—*Garnets* on Indian River, in the village.

Pamelia.—*Agaric mineral,* calc tufa.

Pierrepont.—Tourmaline, sphene, scapolite, hornblende.

Pillar Point.—*Massive barite* (exhausted).

Theresa.—*Fluorite, calcite,* hematite, hornblende, *quartz crystal,* serpentine (associated with hematite), celestite, strontianite.

Watertown.—*Tremolite, agaric mineral,* calc tufa, celestite.

Wilna.—One mile north of Natural Bridge, *calcite.*

LEWIS CO.—Diana (localities mostly near junction of crystalline and sedimentary rocks, and within two miles of Natural Bridge).—*Scapolite!* wollastonite, *green coccolite, feldspar, tremolite, pyroxene! sphene! !* mica, *quartz crystals,* drusy quartz, cryst. pyrite, pyrrhotite, *blue calcite,* serpentine, *rensselaerite,* zircon, graphite, chlorite, hematite, bog-iron ore, iron sand, *apatite.*

Greig.—*Magnetite,* pyrite.

Lowville.—*Calcite,* fluorite, pyrite, galenite, blende, calc tufa.

Martinsburgh.—Wad, galenite, etc., but mine not now opened, *calcite.*

MONROE CO.—Rochester.—*Pearl spar,* calcite, snowy gypsum, fluor, celestite, galenite, blende, barite, hornstone.

MONTGOMERY CO.—Palatine.—*Quartz crystals,* drusy quartz, anthracite, hornstone, agate, garnet.

Root.—*Drusy quartz, blende,* barite, stalactite, stalagmite, galenite, pyrite.

NEW YORK CO.—Corlear's Hook.—Apatite, brown and yellow feldspar, sphene.

Harlem.—Epidote, apophyllite, stilbite, tourmaline, vivianite, lamellar feldspar, mica.

Kingsbridge.—*Tremolite, pyroxene, mica, tourmaline,* pyrite, rutile, dolomite.

New York.—*Serpentine, amianthus,* actinolite, *pyroxene,* hydrous anthophyllite, garnet, staurolite, molybdenite, graphite, *chlorite,* jasper, *necronite,* feldspar. In the excavations for the 4th Avenue tunnel, 1875, *harmotome,* stilbite, chabazite, heulandite, etc.

NIAGARA CO.—Lewiston.—*Epsomite.*

Lockport.—*Celestite, calcite, selenite, anhydrite, fluorite,* dolomite, *blende.*

Niagara Falls.—*Calcite,* fluorite, blende, *dolomite.*

ONEIDA CO.—Boonville.—*Calcite, wollastonite, coccolite.*

Clinton.—*Blende, lenticular argillaceous iron ore* in rocks of the Clinton group, strontianite, celestite, the former covering the latter.

ONONDAGA CO.—Camillus.—*Selenite* and *fibrous gypsum.*

Cold Spring.—Axinite.

Manlius.—*Gypsum* and fluor.

Syracuse.—*Serpentine,* celestite, selenite, barite.

ORANGE CO.—CORNWALL.—*Zircon, chondrodite, hornblende, spinel, massive feldspar, fibrous epidote,* hudsonite, menaccanite, *serpentine,* coccolite.

DEER PARK.—*Cryst. pyrite,* galenite.

MONROE.—*Mica! sphene! garnet,* colophonite, *epidote, chondrodite, allanite,* bucholzite, brown spar, *spinel,* hornblende, talc, menaccanite, *pyrrhotite,* pyrite, chromite, *graphite,* rastolyte, moronolite.

At WILKS and O'NEILL Mine in Monroe.—Aragonite, *magnetite,* dimagnetite (pseud.?), jenkinsite, *asbestus,* serpentine, *mica, hortonolite.*

At TWO PONDS in Monroe.—*Pyroxene! chondrodite, hornblende, scapolite! zircon, sphene,* apatite.

At GREENWOOD FURNACE in Monroe.—*Chondrodite, pyroxene! mica, hornblende, spinel, scapolite, biotite!* menaccanite.

At FOREST OF DEAN.—*Pyroxene, spinel,* zircon, scapolite, hornblende.

TOWN OF WARWICK, WARWICK VILLAGE.—*Spinel! zircon, serpentine! brown spar, pyroxene! hornblende! pseudomorphous steatite, feldspar!* (Rock Hill), menaccanite, *clintonite,* tourmaline (R. H.), *rutile, sphene,* molybdenite, arsenopyrite, marcasite, pyrite, yellow iron sinter, quartz, jasper, mica, coccolite.

AMITY.—*Spinel! garnet, scapolite, hornblende, vesuvianite, epidote! clintonite! magnetite, tourmaline,* warwickite, *apatite, chondrodite, talc! pyroxene!* rutile, menaccanite, *zircon, corundum, feldspar,* sphene, calcite, serpentine, schiller spar (?), silvery mica.

EDENVILLE.—*Apatite, chondrodite! hair-brown hornblende!* tremolite, *spinel, tourmaline, warwickite, pyroxene, sphene, mica, feldspar,* arsenopyrite, orpiment, *rutile,* menaccanite, scorodite, chalcopyrite, *leucopyrite* (or lŏllingite), allanite.

WEST POINT.—*Feldspar, mica,* scapolite, *sphene, hornblende,* allanite.

PUTNAM CO.—BREWSTER, Tilly Foster Iron Mine.—*Chondrodite!* (also humite and clino-humite) crystals very rare, *magnetite, dolomite, serpentine, pseudomorphs, brucite,* enstatite, ripidolite, biotite, actinolite, apatite, pyrrhotite, fluorite, albite, epidote, sphene.

ANTHONY'S NOSE, at top, pyrite, pyrrhotite, pyroxene, hornblende, magnetite.

CARMEL (Brown's quarry).—Anthophyllite, schiller spar (?), orpiment, arsenopyrite, epidote.

COLD SPRING.—Chabazite, mica, sphene, epidote.

PATTERSON.—*White pyroxene! calcite, asbestus, tremolite,* dolomite, massive pyrite.

PHILLIPSTOWN.—*Tremolite, amianthus, serpentine, sphene, diopside, green coccolite,* hornblende, *scapolite,* stilbite, mica, laumontite, gurhofite, calcite, magnetite, chromite.

PHILLIPS Ore Bed.—Hyalite, *actinolite, massive pyrite.*

RENSSELAER CO.—HOOSIC.—Nitrogen springs.

LANSINGBURGH.—Epsomite, *quartz crystals, pyrite.*

TROY.—*Quartz crystals, pyrite, selenite.*

RICHMOND CO.—ROSSVILLE.—Lignite, *cryst. pyrite.*

QUARANTINE.—*Asbestus, amianthus,* aragonite, *dolomite, gurhofite* brucite, serpentine, *talc,* magnesite.

ROCKLAND CO.—CALDWELL.—*Calcite.*

GRASSY POINT.—Serpentine, actinolite.

HAVERSTRAW.—*Hornblende*, barite.

LADENTOWN.—Zircon, malachite, cuprite.

PIERMONT.—Datolite, stilbite, apophyllite, stellite, prehnite, thomsonite, calcite, chabazite.

ST. LAWRENCE CO.—CANTON.—*Massive pyrite, calcite*, brown tourmaline, *sphene, serpentine*, talc, *rensselaerite*, pyroxene, hematite, chalcopyrite.

DE KALB.—*Hornblende*, barite, *fluorite, tremolite, tourmaline*, blende, graphite, pyroxene, quartz (spongy), serpentine.

EDWARDS.—*Brown* and *silvery mica!* scapolite, apatite, *quartz crystals*, actinolite, *tremolite!* hematite, serpentine, magnetite.

FINE.—*Black mica*, hornblende.

FOWLER.—*Barite, quartz crystals!* hematite, *blende*, galenite, tremolite, chalcedony, bog ore, satin spar (assoc. with serpentine), pyrite, chalcopyrite, actinolite, *rensselaerite* (near Somerville).

GOUVERNEUR.—*Calcite! serpentine! hornblende! scapolite! orthoclase, tourmaline!* idocrase (one mile south of G.), pyroxene, malacolite, apatite, *rensselaerite*, serpentine, *sphene*, fluorite, barite (farm of Judge Dodge), black *mica*, phlogopite, *tremolite!* asbestus, hematite, graphite, vesuvianite (near Somerville in serpentine), *spinel*, houghite, scapolite, *phlogopite*, dolomite; three-quarters of a mile west of Somerville, *chondrodite*, spinel; two miles north of Somerville, *apatite*, pyrite, *brown tourmaline!!*

HAMMOND.—*Apatite! zircon!* (farm of Mr. Hardy), *orthoclase* (loxoclase), *pargasite*, barite, pyrite, purple fluorite, dolomite.

HERMON.—*Quartz crystals*, hematite, siderite, pargasite, pyroxene, serpentine, tourmaline, bog-iron ore.

MACOMB.—Blende, mica, *galenite* (on land of James Averill), sphene.

MINERAL POINT, Morristown.—Fluorite, blende, galenite, *phlogopite* (Pope's Mills), barite.

OGDENSBURGH.—Labradorite.

PITCAIRN.—Satin spar, associated with serpentine.

POTSDAM.—*Hornblende!*; eight miles from Potsdam, on road to Pierrepont, *feldspar, tourmaline, black mica*, hornblende.

ROSSIE (Iron Mines).—*Barite*, hematite, coralloidal aragonite in mines near Somerville, limonite, *quartz* (sometimes stalactitic at Parish Iron Mine), *pyrite, pearl spar.*

ROSSIE Lead Mine.—*Calcite! galenite! pyrite, celestite*, chalcopyrite, hematite, cerussite, anglesite, *octahedral fluor, black phlogopite.*

Elsewhere in ROSSIE.—*Calcite*, barite, quartz crystals, chondrodite (near Yellow Lake), *feldspar! pargasite! apatite, pyroxene*, hornblende, sphene, zircon, *mica*, fluorite, serpentine, automolite, pearl spar, graphite.

RUSSEL.—*Pargasite, specular iron, quartz* (dodec.), calcite, serpentine, rensselaerite, magnetite.

SARATOGA CO.—GREENFIELD.—*Chrysoberyl! garnet! tourmaline! mica, feldspar*, apatite, graphite, aragonite (in iron mines).

SCHOHARIE CO.—BALL'S CAVE, and others.—Calcite, stalactites.

CARLISLE.—*Fibrous barite, cryst. and fibrous calcite.*

MIDDLEBURY.—Asphaltic coal, calcite.

SHARON.—Calcareous tufa.

SCHOHARIE.—Fibrous celestite, *strontianite! cryst. pyrite!*

SENECA CO.—**Canoga.**—*Nitrogen springs.*

SULLIVAN CO.—**Wurtzboro'.**—*Galenite, blende, pyrite, chalcopyrite.*

TOMPKINS CO.—**Ithaca.**—Calcareous tufa.

ULSTER CO. — **Ellenville.** — *Galenite,* blende, *chalcopyrite! quartz, brookite.*

Marbletown.—Pyrite.

WARREN CO.—**Caldwell.**—*Massive feldspar.*

Chester.—*Pyrite,* tourmaline, rutile, chalcopyrite.

Diamond Isle (Lake George).—*Calcite, quartz crystals.*

Glenn's Falls.—Rhomb spar.

Johnsburgh.—*Fluorite! zircon! graphite, serpentine, pyrite.*

WASHINGTON CO.—**Fort Ann.**—*Graphite,* serpentine.

Granville.—*Lamellar pyroxene,* massive feldspar, epidote.

WAYNE CO.—**Wolcott.**—Barite.

WESTCHESTER CO.—**Anthony's Nose.**—*Apatite,* pyrite, *calcite!* in very large tabular crystals, grouped, and sometimes incrusted with drusy quartz.

Davenport's Neck.—*Serpentine,* garnet, sphene.

Eastchester.—Blende, pyrite, chalcopyrite, dolomite.

Hastings.—*Tremolite, white pyroxene.*

New Rochelle.—*Serpentine,* brucite, quartz, *mica,* tremolite, garnet, magnesite.

Peekskill.—Mica, feldspar, hornblende, stilbite, sphene; three miles south, emery.

Rye.—*Serpentine, chlorite, black tourmaline,* tremolite.

Sing Sing.—*Pyroxene, tremolite, pyrite,* beryl, azurite, green malachite, cerussite, pyromorphite, anglesite, vauquelinite, galenite, native silver, chalcopyrite.

West Farms.—Apatite, tremolite, garnet, stilbite, heulandite, chabazite, epidote, sphene.

Yonkers.—*Tremolite,* apatite, calcite, analcite, *pyrite,* tourmaline.

Yorktown.—*Fibrolite, monazite,* magnetite.

WYOMING CO.—**Wyoming.**—Rock salt.

NEW JERSEY.

Andover Iron Mine (Sussex Co.)—Willemite, brown garnet.

Allentown (Monmouth Co.)—*Vivianite, dufrenite.*

Bellville.—Copper mines.

Bergen.—*Calcite! datolite! pectolite! analcite, apophyllite! gmelinite, prehnite,* sphene, *stilbite, natrolite,* heulandite, laumontite, *chabazite,* pyrite, pseudomorphous steatite imitative of apophyllite, diabantite.

Brunswick.—Copper mines: *native copper, malachite, mountain leather.*

Bryam.—Chondrodite, *spinel,* at Roseville, *epidote.*

Cantwell's Bridge (Newcastle Co.), three miles west.—Vivianite.

Danville (Jemmy Jump Ridge).—*Graphite,* chondrodite, augite, mica.

Flemington.—*Copper mines.*

Frankfort.—*Serpentine.*

Franklin and Sterling (Sussex Co.).—*Spinel! garnet! rhodonite! willemite! franklinite! zincite! dysluite! hornblende, tremolite, chondrodite, white scapolite, black tourmaline, epidote, mica,* actinolite, augite, sahlite, cocolite, asbestus, *jeffersonite* (augite). calamine, graphite, fluorite, beryl, galenite, serpentine, honey-colored sphene, quartz, chalcedony, amethyst, zircon, molybdenite, vivianite, *tephroite*, rhodochrosite, aragonite, sussexite, chalcophanite, rœpperite, calcozincite, vanuxemite, gahnite, hetærolite. Also *algerite* in gran. limestone.

Franklin and Warwick Mts.—*Pyrite.*

Greenbrook.—Copper mines.

Griggstown.—Copper mines.

Hamburgh.—One mile north, *spinel! tourmaline, phlogopite, hornblende, limonite,* hematite.

Hoboken.—Serpentine (marmolite), *brucite, nemalite* (or fibrous brucite), aragonite, dolomite.

Hurdstown.—*Apatite,* pyrrhotite, magnetite.

Imlaystown.—Vivianite.

Lockwood.—*Graphite, chondrodite, talc, augite, quartz, green spinel.*

Montville (Morris Co.)—Serpentine, *chrysotile.*

Mullica Hill (Gloucester Co.)—*Vivianite* lining belemnites and other fossils.

Newton.—*Spinel,* blue, pink, and white corundum, *mica,* vesuvianite, *hornblende, tourmaline, scapolite,* rutile, pyrite, talc, calcite, barite, *pseudomorphous steatite.*

Paterson.—*Datolite.*

Vernon.—Serpentine, spinel, hydrotalcite.

PENNSYLVANIA.*

ADAMS CO.—Gettysburg.—Epidote, fibrous and massive.

BERKS Co.—Morgantown.—At Jones's mines, one mile east of Morgantown, *malachite,* native copper, *chrysocolla, magnetite,* allophane, pyrite, chalcopyrite, aragonite, apatite, talc, venerite; two miles N. E. from Jones's mine, graphite, sphene; at Steele's mine, one mile N. W. from St. Mary's, Chester Co., *magnetite,* micaceous iron, coccolite, brown garnet.

Reading.—*Smoky quartz* crystals, *zircon,* stilbite, iron ore; near Pricetown, zircon, allanite, epidote; at Eckhardt's Furnace, *allanite* with *zircon;* at Zion's Church, molybdenite; near Kutztown, in the Crystal Cave, stalactites; at Fritz Island, *apophyllite,* thomsonite, *chabazite,* calcite, azurite, *malachite,* magnetite, chalcopyrite, stibnite, prochlorite, precious serpentine.

BUCKS CO.—Buckingham Township.—Crystallized quartz; near New Hope, vesuvianite, epidote, barite.

Southampton.—Near the village of Feasterville, in the quarry of George Van Arsdale, *graphite,* pyroxene, sahlite, coccolite, *sphene,* green mica, calcite, *wollastonite,* glassy feldspar sometimes opalescent, phlogopite, *blue quartz,* garnet, zircon, pyrite, moroxite, scapolite.

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* See also the Report on the Mineralogy of Pennsylvania, by Dr. F. A. Genth, 1875.

New Britain.—Dolomite, galenite, blende, malachite.

CARBON CO.—Summit Hill, in coal mines.—*Kaolinite.*

CHESTER CO.—Avondale.—Asbestus, tremolite, garnet, opal.

Birmingham Township.—Amethyst, *smoky quartz,* serpentine, beryl; in Ab'm Darlington's lime quarry, calcite.

East Bradford.—Near Buffington's bridge, on the Brandywine, green, blue, and gray cyanite, the gray cyanite found loose in the soil, in crystals; on the farms of Dr. Elwyn, Mrs. Foulke, Wm. Gibbons, and Saml. Entrikin, *amethyst.* At Strode's mill, asbestus, *magnesite,* anthophyllite, epidote, aquacrepitite, oligoclase, drusy quartz, *collyrite?* on Osborne's Hill, *wad, manganesian garnet* (massive), *sphene* schorl; at Caleb Cope's lime quarry, *fetid dolomite,* necronite, garnets, blue cyanite, *yellow actinolite in talc;* near the Black Horse Inn, *indurated talc,* rutile; on Amos Davis's farm, *orthite!* massive, from a grain to lumps of one pound weight; near the paper-mill on the Brandywine, *zircon,* associated with *titaniferous iron* in blue quartz.

West Bradford.—Near the village of Marshalton, *green cyanite,* rutile, scapolite, pyrite, staurolite; at the Chester County Poor-house limestone quarry, *chesterlite!* in crystals implanted on dolomite, *rutile!* in brilliant acicular crystals, which are finely terminated, calcite in scalenohedrons, zoisite, *damourite?* in radiated groups of crystals on dolomite, *quartz crystals;* on Smith & McMullin's farm, epidote.

Charlestown.—*Pyromorphite, cerussite, galenite,* quartz.

Coventry.—Allanite, near Pughtown.

South Coventry.—In Chrisman's limestone quarry, near Coventry village, augite, sphene, graphite, *zircon* in iron ore (about half a mile from the village).

East Fallowfield.—Soapstone.

East Goshen.—Serpentine, *asbestus,* magnetite (lodestone), garnet.

Elk.—Menaccanite with muscovite, chromite; at Lewisville, *black tourmaline.*

West Goshen.—On the Barrens, one mile north of West Chester, amianthus, serpentine, cellular quartz, jasper, chalcedony, drusy quartz, chlorite, marmolite, indurated talc, *magnesite* in radiated crystals on serpentine, hematite, *asbestus;* near R. Taylor's mill, chromite in octahedral crystals, *deweylite, radiated magnesite,* aragonite, *staurolite,* garnet, asbestus, epidote; *zoisite* on hornblende at West Chester water-works (not accessible at present).

New Garden.—At Nivin's limestone quarry, *brown tourmaline, necronite,* scapolite, apatite, brown and green mica, rutile, *aragonite, fibrolite, kaolinite,* tremolite.

Kennett.—Actinolite, brown tourmaline, brown mica, *epidote,* tremolite, scapolite, *aragonite;* on Wm. Cloud's farm, *sunstone!!* chabazite, sphene. At Pearce's old mill, zoisite, *epidote, sunstone;* sunstone occurs in good specimens at various places in the range of hornblende rocks running through this township from N. E. to S. W.

Lower Oxford.—Garnets, *pyrite* in cubic crystals.

London Grove.—Rutile, jasper, chalcedony (botryoidal), large and rough quartz crystals, epidote; on Wm. Jackson's farm, *yellow and black tourmaline, tremolite,* rutile, green mica, apatite; at Pusey's quarry, rutile, *tremolite.*

East Marlborough.—On the farm of Bailey & Brother, one mile south of Unionville, bright *yellow* and nearly white *tourmaline, chesterlite, albite*, pyrite; near Marlborough meeting-house, epidote, serpentine, acicular black tourmaline in white quartz; *zircon* in small perfect crystals loose in the soil at Pusey's sawmill, two miles S. W. of Unionville.

West Marlborough.—Near Logan's quarry, staurolite, cyanite, yellow tourmaline, rutile, garnets; near Doe Run village, *hematite*, scapolite, *tremolite;* in R. Baily's limestone quarry, two and a half miles S. W. of Unionville, *fibrous tremolite, cyanite*, scapolite.

Newlin.—On the serpentine barrens, one and a half mile N. E. of Unionville, *corundum!* massive and crystallized, also in crystals in *albite*, often in loose crystals covered with a thin coating of steatite, spinel (black), talc, picrolite, brucite, *green tourmaline* with flat pyramidal terminations in albite, *unionite* (rare), *euphyllite*, mica in hexagonal crystals, *feldspar, beryl!* in hexagonal crystals one of which weighs 51 lbs., pyrite in cubic crystals, chromic iron, drusy quartz, green quartz, actinolite, *emerylite*, chloritoid, diallage, *oligoclase;* on Johnson Patterson's farm, massive *corundum*, titaniferous iron, *clinochlore, emerylite*, sometimes colored green by chrome, albite, *orthoclase*, halloysite, margarite, garnets, *beryl;* on J. Lesley's farm, *corundum*, crystallized and in massive lumps one of which weighed 5,200 lbs., *diaspore!! emerylite! euphyllite crystallized! green tourmaline*, in transparent crystals in the *euphyllite*, orthoclase; two miles N. of Unionville, *magnetite* in octahedral crystals; one mile E. of Unionville, *hematite;* in Edwards's old limestone quarry, purple fluorite, rutile.

East Nottingham.—*Asbestus, chromite* in crystals, hallite, beryl.

West Nottingham.—At Scott's chrome mine, *chromite, foliated talc*, marmolite, serpentine, *chalcedony, rhodochrome;* near Moro Phillips's chrome mine, *asbestus;* at the magnesia quarry, *deweylite*, marmolite, magnesite, leelite, serpentine, chromite; near Fremont P. O., corundum.

West Pikeland.—In the iron mines near Chester Springs, *gibbsite, zircon, turgite, hematite* (stalactitical and in geodes), göthite.

Penn.—Garnets, agalmatolite.

Pennsbury.—On John Craig's farm, brown garnets, *mica;* on J. Dilworth's farm, near Fairville, *muscovite!* in the village of Fairville, *sunstone;* near Brinton's Ford, on the Brandywine, *chondrodite, sphene*, diopside, *augite*, coccolite; at Mendenhall's old limestone quarry, *fetid quartz*, sunstone; at Swain's quarry, orthoclase.

Pocopson.—On the farms of John Entrikin and Jos. B. Darlington, *amethyst.*

Sadsbury.—*Rutile!!* splendid geniculated crystals are found loose in the soil for seven miles along the valley, and particularly near the village of Parkesburg, where they sometimes occur weighing one pound, doubly geniculated and of a deep red color; near Sadsbury village, *amethyst*, tourmaline, epidote, *milk quartz.*

Schuylkill.—In the railroad tunnel at Phœnixville, *dolomite!* sometimes coated with pyrite, quartz crystals, yellow blende, brookite, *calcite* in hexagonal crystals enclosing *pyrite;* at the Wheatley, Brookdale, and Chester County Lead Mines, one and a half mile S. of Phœnixville, *pyromorphite! cerussite! galenite, anglesite!!* quartz crystals, chalcopyrite, barite, *fluorite* (white), *stolzite, wulfenite!*

calamine, vanadinite, blende! mimetite! descloizite, göthite, chrysocolla, native copper, malachite, *azurite,* limonite, *calcite, sulphur,* pyrite, melaconite, pseudomalachite, gersdorffite, chalcocite? covellite.

Thornbury.—On Jos. H. Brinton's farm, *muscovite* containing acicular crystals of tourmaline, *rutile,* titaniferous iron.

Tredyffrin.—*Pyrite* in cubic crystals loose in the soil.

Uwchlan.—Massive *blue quartz, graphite.*

Warren.—*Melanite,* feldspar.

West Goshen (one mile from West Chester).—Chromite.

Willistown.—*Magnetite, chromite,* actinolite, asbestus.

West Town.—On the serpentine rocks, 3 miles S. of West Chester, *clinochlore! jefferisite!* mica, asbestus, actinolite, magnesite, *talc,* titaniferous iron, magnetite and massive tourmaline.

East Whiteland.—*Pyrite,* in cubic crystals, quartz crystals.

West Whiteland.—At Gen. Trimble's iron mine (southeast), *stalactitic hematite! wavellite!!* in radiated stalactites, gibbsite, cœruleolactile.

Warwick.—At the Elizabeth mine and Keim's old iron mine adjoining, one mile N. of Knauertown, *aplome garnet!* in brilliant dodecahedrons, *flosferri, pyroxene, micaceous hematite, pyrite* in bright octahedral crystals in calcite, chrysocolla, chalcopyrite massive and in single tetrahedral crystals, magnetite, *fascicular hornblende! bornite,* malachite, *brown garnet,* calcite, *byssolite!* serpentine; near the village of St. Mary's, magnetite in dodecahedral crystals, *melanite, garnet, actinolite* in small radiated nodules; at the Hopewell iron mine, one mile N. W. of St. Mary's, *magnetite* in octahedral crystals.

COLUMBIA CO.—At Webb's mine, yellow blende in calcite; near Bloomburg, cryst. magnetite.

DAUPHIN CO.—Near Hummelstown.—Green garnets, cryst. *smoky quartz,* feldspar, *micaceous hematite, stilbite, chrysocolla.*

DELAWARE CO.—Aston Township.—*Amethyst, corundum,* emerylite, staurolite, *fibrolite,* black tourmaline, *margarite, sunstone, asbestus,* anthophyllite, steatite; near Tyson's mill, garnet, staurolite; at Peter's milldam in the creek, *pyrope garnet.*

Birmingham.—*Fibrolite, kaolin* (abundant), crystals of rutile, *amethyst;* at Bullock's old quarry, zircon, *bucholzite,* nacrite, yellow crystallized quartz, *feldspar.*

Blue Hill.—Green quartz crystals, spinel.

Chester.—*Amethyst, black tourmaline, beryl, crystals of feldspar, garnet,* cryst. pyrite, *molybdenite, molybdite,* chalcopyrite, kaolin, uraninite, *muscovite,* orthoclase, bismutite.

Chichester.—Near Trainer's milldam, *beryl,* tourmaline, crystals of *feldspar,* kaolin; on Wm. Eyre's farm, *tourmaline.*

Concord.—*Mica, feldspar, kaolin, drusy quartz,* meerschaum, stellated *tremolite, anthophyllite,* fibrolite, acicular crystals of *rutile,* pyrope in quartz, amethyst, actinolite, *manganesian garnet, beryl;* in Green's creek, *pyrope garnet.*

Darby.—*Blue* and *gray cyanite,* garnet, staurolite, zoisite, quartz, beryl, chlorite, mica, limonite.

Edgemont.—*Amethyst,* oxide of manganese, crystals of *feldspar;* one mile east of Edgemont Hall, *rutile* in quartz.

Green's Creek.—*Garnet* (so-called pyrope).

Haverford.—Staurolite with garnet.

MARPLE.—*Tourmaline, andalusite,* amethyst, *actinolite, anthophyllite,* talc, *radiated actinolite* in talc, chromite, *drusy quartz,* beryl, cryst. pyrite, *menaccanite in quartz,* chlorite.

MIDDLETOWN.—*Amethyst, beryl,* black mica, *mica* with reticulated magnetite between the plates, *manganesian garnets!* large trapezohedral crystals, some 3 in. in diameter, indurated talc, hexagonal crystals of *rutile, crystals of mica, green quartz! anthophyllite,* radiated tourmaline, staurolite, titanic iron, fibrolite, serpentine; at Lenni, *chlorite,* green and bronze *vermiculite! green feldspar;* at Mineral Hill, fine crystals of *corundum,* one of which weighs 1¾ lb., *actinolite* in great variety, bronzite, *green feldspar, moonstone, sunstone, graphic granite,* magnesite, *octahedral crystals of chromite* in great quantity, *beryl,* chalcedony, asbestus, *fibrous hornblende,* rutile, staurolite, melanosiderite, hallite; at Painter's Farm, near Dismal Run, *zircon* with oligoclase, tremolite, tourmaline; at the Black Horse, near Media, corundum; at Hibbard's Farm and at Fairlamb's Hill, chromite in brilliant octahedrons.

NEWTOWN.—Serpentine, hematite, enstatite, tremolite.

UPPER PROVIDENCE.—*Anthophyllite, tremolite, radiated asbestus, radiated actinolite,* tourmaline, *beryl, green feldspar, amethyst* (one found on Morgan Hunter's farm weighing over 7 lbs.), *andalusite!* (one terminated crystal found on the farm of Jas. Worrell weighs 7½ lbs.); at Blue Hill, very fine crystals of *blue quartz* in chlorite, *amianthus* in serpentine, zircon.

LOWER PROVIDENCE.—*Amethyst, green mica;* garnet, large crystals of *feldspar!* (some over 100 lbs. in weight).

RADNOR.—*Garnet,* marmolite, deweylite, chromite, asbestus, magnesite, talc, blue quartz, picrolite, limonite, magnetite.

SPRINGFIELD.—*Andalusite, tourmaline,* beryl, titanic iron, garnet; on Fell's Laurel Hill, beryl, garnet; near Beattie's mill, staurolite, apatite; near Lewis's paper-mill, tourmaline, *mica.*

THORNBURY.—*Amethyst.*

HUNTINGDON CO.—NEAR FRANKSTOWN.—In the bed of a stream and on the side of a hill, *fibrous celestite* (abundant), *quartz crystals.*

LANCASTER CO.—DRUMORE TOWNSHIP.—Quartz crystals.

FULTON.—At Wood's chrome mine, near the village of Texas, *brucite!!* zaratite (emerald nickel), *pennite! ripidolite! kämmererite! baltimorite, chromite,* williamsite, *chrysolite!* marmolite, *picrolite,* hydromagnesite, *dolomite,* magnesite, *aragonite,* calcite, serpentine, hematite, menaccanite, genthite, chrome-garnet, bronzite, millerite; at Low's mine, *hydromagnesite, brucite* (lancasterite), *picrolite,* magnesite, *williamsite, chromic iron,* talc, zaratite, baltimorite, serpentine, hematite; on M. Boice's farm, one mile N. W. of the village, *pyrite* in cubes and various modifications, *anthophyllite;* near Rock Springs, *chalcedony,* carnelian, *moss agate, green tourmaline* in talc, titanic iron, chromite, *octahedral magnetite in chlorite;* at Reynolds's old mine, calcite, *talc,* picrolite, *chromite;* at Carter's chrome mine, brookite.

GAP MINES.—Chalcopyrite, *pyrrhotite* (niccoliferous), *millerite* in botryoidal radiations, *vivianite!* (rare), actinolite, *siderite,* hisingerite, pyrite.

PEQUA VALLEY.—Eight miles south of Lancaster, argentiferous galenite (said to contain 250 to 300 ounces of silver to the ton?), vauquelinite, rutile at Pequea mine; four miles N. W. of Lancaster, on the Lancaster and Harrisburg Railroad, *calamite*, galenite, blende; *pyrite* in cubic crystals is found in great abundance near the city of Lancaster; at the Lancaster zinc mines, *calamine*, blende, tennantite? *smithsonite* (pseud. of dolomite), *aurichalcite*.

LEBANON CO.—Cornwall.—*Magnetite*, *pyrite* (cobaltiferous), chalcopyrite, *native copper*, *azurite*, *malachite*, *chrysocolla*, *cuprite* (hydrocuprite), *allophane*, *brochantite*, serpentine, quartz pseudomorphs; *galenite* (with octahedral cleavage), fluorite, covellite, hematite (micaceous), opal, asbestus.

LEHIGH CO.—Friedensville.—At the zinc mines, *calamine*, *smithsonite*, hydrozincite, massive blende, greenockite, quartz, allophane, zinciferous clay, mountain leather, aragonite, sauconite; near Allentown, magnetite, pipe-iron ore; near Bethlehem, on S. Mountain, allanite, with zircon and altered sphene in a single isolated mass of syenite, magnetite, martite, black spinel, tourmaline, chalcocite.

MIFFLIN CO.—Strontianite.

MONROE CO.—In Cherry Valley.—*Calcite*, chalcedony, quartz; in Poconac Valley, near Judge Mervine's, cryst. quartz.

MONTGOMERY CO.—Conshohocken.—Fibrous tourmaline, menaccanite, aventurine quartz, phyllite; in the quarry of Geo. Bullock, *calcite* in hexagonal prisms, aragonite.

Lower Providence.—At the Perkiomen lead and copper mines, near the village of Shannonville, azurite, *blende*, *galenite*, pyromorphite, cerussite, wulfenite, anglesite, barite, calamine, chalcopyrite, malachite, chrysocolla, *brown spar*, cuprite, covellite (rare), melaconite, libethenite, pseudomalachite.

White Marsh.—At D. O. Hitner's iron mine, five and a half miles from Spring Mills, limonite in geodes and stalactites, *göthite*, pyrolusite, wad, lepidocrocite; at Edge Hill Street, North Pennsylvania Railroad, titanic iron, braunite, pyrolusite; one mile S. W. of Hitner's iron mine, *limonite*, velvety, stalactitic, and fibrous, fibres three inches long, turgite, *göthite*, pyrolusite, *velvet manganese*, wad; near Marble Hall, at Hitner's marble quarry, white marble, granular barite, resembling marble; at Spring Mills, limonite, pyrolusite, göthite; at Flat Rock Tunnel, opposite Manayunk, *stilbite*, *heulandite*, *chabasite*, ilvaite, beryl, feldspar, mica.

Lafayette, at the Soapstone quarries.—Talc, jefferisite, garnet, albite, serpentine, zoisite, staurolite, chalcopyrite; at Rose's Serpentine quarry, opposite Lafayette, enstatite, serpentine.

NORTHAMPTON CO.—Bushkill Township.—Crystal Spring on Blue Mountain, *quartz crystals*.

Near Easton.—*Zircon!* (exhausted), nephrite, coccolite, tremolite, pyroxene, sahlite, limonite, magnetite, purple calcite.

Williams Township.—Pyrolusite in geodes in limonite beds, göthite (lepidocrocite) at Glendon.

NORTHUMBERLAND CO.—Opposite Selin's Grove.—Calamine.

PHILADELPHIA CO.—Frankford.—Titanite in gneiss, apophyllite; on the Philadelphia, Trenton and Connecting Railroad, basanite; at the quarries on Frankford Creek, stilbite, molybdenite, hornblende; on the Connecting Railroad, wad, earthy cobalt; at Chestnut Hill, magnetite, green mica, chalcopyrite, fluorite.

Fairmount Water-Works.—In the quarries opposite Fairmount, *autunite! torbernite*, crystals of *feldspar*, beryl, pseudomorphs after beryl, tourmaline, albite, wad, menaccanite.

Gorgas's and Crease's Lane.—Tourmaline, cyanite, staurolite, hornstone.

Near Germantown.—*Black tourmaline*, laumontite, *apatite;* York Road, tourmaline, beryl.

Hestonville.—Alunogen, iron alum, orthoclase.

Heft's Mill.—Alunogen, tourmaline, cyanite, titanite.

Manayunk.—At the soapstone quarries above Manayunk, talc, *steatite*, chlorite, vermiculite, *anthophyllite*, staurolite, dolomite, apatite, asbestus, brown spar, epsomite.

Megargee's Paper-mill.—Staurolite, titanic iron, hyalite, *apatite*, green mica, iron garnets in great abundance.

McKinney's Quarry, on Rittenhouse Lane.—Feldspar, *apatite, stilbite*, natrolite, *heulandite*, epidote, hornblende, erubescite, malachite.

Schuylkill Falls.—Chabazite, titanite, fluorite, epidote, muscovite, tourmaline, prochlorite.

SCHUYLKILL CO.—Tamaqua, near Pottsville, in coal mines.—*Kaolinite.*

YORK CO.—Bornite, rutile in slender prisms in granular quartz.

DELAWARE.

NEWCASTLE CO.—Brandywine Springs.—*Bucholzite, fibrolite* abundant, sahlite, pyroxene; Brandywine Hundred, muscovite, enclosing reticulated magnetite.

Dixon's Feldspar Quarries, six miles N. W. of Wilmington (quarries worked for the manufacture of porcelain).—*Adularia, albite, oligoclase, beryl, apatite, cinnamon-stone!!* magnesite, serpentine, asbestus, black *tourmaline!* (rare), *indicolite!* (rare), sphene in pyroxene, cyanite.

Dupont's Powder Mills.—"Hypersthene."

Eastburn's Limestone Quarries, near the Pennsylvania line.—*Tremolite, bronzite.*

Quarryville.—Garnet, spodumene, fibrolite.

Near Newark, on the railroad.—Sphærosiderite on drusy quartz, jasper (ferruginous opal), cryst. spathic iron in the cavities of cellular quartz.

Way's Quarry, two miles south of Centreville.—*Feldspar* in fine cleavage masses, *apatite, mica, deweylite, granular quartz.*

Wilmington.—In Christiana quarries, *metalloidal diallage.*

Kennett Turnpike, near Centreville.—Cyanite and garnet.

HARTFORD CO.—Deweylite.

KENT CO.—Near Middletown, in Wm. Polk's marl pits.—*Vivianite!*

On Chesapeake and Delaware Canal.—Retinasphalt, pyrite, amber.

SUSSEX CO.—Near Cape Henlopen.—Vivianite,

MARYLAND.

Baltimore (Jones's Falls, 1¾ mile from B.).—Chabazite (haydenite), heulandite (beaumontite of Levy), pyrite, lenticular carbonate of iron, *mica, stilbite.*

Sixteen miles from Baltimore, on the Gunpowder.—*Graphite.*

Twenty-three miles from B., on the Gunpowder.—*Talc.*

Twenty-five miles from B., on the Gunpowder.—*Magnetite, sphene,* pycnite.

Thirty miles from B., in Montgomery Co., on farm of S. Eliot.—Gold in quartz.

Eight to twenty miles north of B., in limestone.—*Tremolite, augite, pyrite,* brown and yellow tourmaline.

Fifteen miles north of B.—*Sky-blue chalcedony* in granular limestone.

Eighteen miles north of B., at Scott's mills.—*Magnetite,* cyanite.

BARE HILLS.—*Chromite, asbestus, tremolite, talc,* hornblende, serpentine, chalcedony, meerschaum, baltimorite, *chalcopyrite,* magnetite.

CAPE SABLE, near Magothy R.—Amber, pyrite, alum slate.

CARROLL CO.—Near Sykesville, Liberty Mines, gold, magnetite, *pyrite* (*octahedrons*), *chalcopyrite,* linnæite (carrollite); at Patapsco Mines, near Finksburg, bornite, *malachite,* siegenite, *linnæite, remingtonite,* magnetite, *chalcopyrite;* at Mineral Hill mine, *bornite,* chalcopyrite, ore of *nickel* (see above), gold, magnetite.

CECIL CO., north part.—*Chromite* in serpentine.

COOPTOWN, Harford Co.—Olive-colored *tourmaline, diallage, talc* of green, blue, and rose colors, *ligniform asbestus, chromite, serpentine.*

DEER CREEK.—*Magnetite!* in chlorite slate.

FREDERICK CO.—Old Liberty mine, near Liberty Town, black copper, malachite, chalcocite, specular iron; at Dollyhyde mine, *bornite,* chalcopyrite, pyrite, argentiferous galenite in dolomite.

MONTGOMERY CO.—*Oxide of manganese.*

SOMERSET and WORCESTER COS., north part.—*Bog-iron ore, vivianite.*

ST. MARY'S RIVER.—*Gypsum!* in clay.

PYLESVILLE, Harford Co.—Asbestus mine.

VIRGINIA, WEST VIRGINIA, AND DISTRICT OF COLUMBIA.

ALBEMARLE CO., a little west of the Green Mts.—*Steatite, graphite,* galenite.

AMHERST CO.—Along the west base of Buffalo Ridge, *copper ores;* on N. W. slope of Friar Mtn., *allanite,* magnetite, zircon, sipylite.

AUGUSTA CO.—At Weyer's (or Weir's) cave, sixteen miles northeast of Staunton, and eighty-one miles northwest of Richmond, calcite, stalactites.

BUCKINGHAM CO.—*Gold* at Garnett and Moseley mines, also, pyrite, pyrrhotite, calcite, garnet; at Eldridge mine (now London and Virginia mines) near by, and the Buckingham mines near Maysville, gold, auriferous pyrite, chalcopyrite, tennantite, *barite; cyanite, tourmaline, actinolite.*

CHESTERFIELD CO.—Near this and Richmond Co., bituminous coal, native coke.

CULPEPPER CO., on Rapidan River.—Gold, pyrite.

FRANKLIN CO.—Grayish steatite.

FAUQUIER CO., Barnett's mills.—Asbestus, gold mines, *barite, calcite.*

Fluvanna Co.—Gold at Stockton's mine; also tetradymite, at "Tellurium mine."

Phenix Copper Mines.—*Chalcopyrite*, etc.

Georgetown, D. C.—Rutile.

Goochland Co.—Gold mines (Moss and Busby's).

Harper's Ferry, on both sides of the Potomac.—Thuringite (owenite) with quartz.

Jefferson Co., at Shepherdstown.—Fluor.

Kanawha Co.—At Kanawha, *petroleum*, brine springs, cannel coal.

Loudon Co.—*Tabular quartz, drase, pyrite, talc, chlorite, soapstone*, asbestus, *chromite, actinolite, quartz crystals; micaceous iron*, bornite, malachite, epidote, near Leesburg (Potomac mine).

Louisa Co.—Walton gold mine, gold, pyrite, chalcopyrite, argentiferous galenite, siderite, blende, anglesite; boulangerite, blende (at Tinder's mine).

Nelson Co.—Galenite, chalcopyrite, malachite.

Orange Co.—Western part, Blue Ridge, specular iron; gold at the Orange Grove and Vaucluse gold mines, worked by the "Freehold" and "Liberty" Mining Companies.

Rockbridge Co., three miles southwest of Lexington.—Barite, strengite.

Shenandoah Co., near Woodstock.—Fluorite.

Mt. Alto, Blue Ridge.—Argillaceous iron ore.

Spottsylvania Co., two miles northeast of Chancellorville.—*Cyanite;* gold mines at the junction of the Rappahannock and Rapidan; on the Rappahannock (Marshall mine); Whitehall mine, affording also tedradymite.

Stafford Co., eight or ten miles from Falmouth.—Micaceous iron, gold, tedradymite, silver, galenite, vivianite.

Washington Co., eighteen miles from Abingdon.—*Rock salt* with *gypsum.*

Wythe Co. (Austin's mines).—*Cerussite, minium, plumbic ochre*, blende, *calamine, galenite*, graphite.

On the Potomac, twenty-five miles north of Washington City.—*Native sulphur* in gray compact limestone.

NORTH CAROLINA.

Ashe Co.—Malachite, chalcopyrite.

Buncombe Co. (now called *Madison Co.*)—Corundum (from a boulder), *margarite*, corundophilite, *garnet*, chromite, barite, *fluorite*, rutile, iron ores, manganese, *zircon;* at Swananoa Gap, cyanite.

Burke Co.—Gold, monazite, zircon, beryl, *corundum, garnet*, sphene, *graphite*, iron ores, tetradymite, montanite (hydrous bismuth tellurate).

Cabarrus Co.—Phenix Mine, gold, barite, *chalcopyrite*, auriferous pyrite, quartz pseudomorph after barite, tetradymite, montanite; Pioneer mines, *gold*, limonite, pyrolusite, *barnhardite, wolfram, scheelite*, cuprotungstite, tungstite, diamond, chrysocolla, chalcocite, molybdenite, *chalcopyrite, pyrite;* White mine, needle ore, chalcopyrite, barite; Long and Muse's mine, argentiferous galenite, pyrite, chalcopyrite, limonite; Boger mine, tetradymite; Fink mine, valuable copper ores; Mt. Makins, tetrahedrite, magnetite, talc, blende, pyrite, proustite, galenite; Bangle mine, scheelite.

Caldwell Co.—Chromite.

Chatham Co.—Mineral coal, pyrite, chloritoid.

Cherokee Co.—Iron ores, gold, galenite, corundum, rutile, cyanite, damonite.

Cleveland Co.—White Plains, *quartz*, crystals, *smoky quartz*, tourmaline, rutile in quartz.

Clay Co.—At the Cullakenee mine and elsewhere, corundum (pink), zoisite, tourmaline, margarite, willcoxite, dudleyite.

Davidson Co.—King's, now Washington mine, native silver, cerussite, anglesite, scheelite, pyromorphite, galenite, blende, malachite, black copper, *wavellite*, garnet, stilbite; five miles from Washington mine, on Faust's farm, gold, *tetradymite*, oxide of bismuth and tellurium, montanite, chalcopyrite, limonite, spathic iron, epidote; near Squire Ward's, gold in crystals, electrum.

Franklin Co.—At Partiss mine, diamonds.

Gaston Co.—Iron ores, corundum, margarite; near Crowder's Mountain (in what was formerly Lincoln Co.), *lazulite*, *cyanite*, *garnet*, graphite; also twenty miles northeast, near south end of Clubb's Mountain, lazulite, cyanite, talc, rutile, topaz, *pyrophyllite;* King's Mountain (or Briggs) mine, native tellurium, altaite, tedradymite, montanite.

Guilford Co.—McCulloch copper and gold mine, twelve miles from Greensboro', *gold*, *pyrite*, *chalcopyrite* (worked for copper), *quartz*, siderite; copper ore at the old Fentress mine; at Deep River, compact *pyrophyllite* (worked for slate-pencils).

Haywood Co.—Corundum, margarite, damourite.

Henderson Co.—*Zircon*, sphene (xanthitane).

Jackson Co.—Alunogen? at Smoky Mountain; at Webster, serpentine, chromite, genthite, *chrysolite*, talc; Hoghalt Mountain, pink corundum, margarite, tourmaline.

Lincoln Co.—Diamond; at Randleman's, *amethyst*, rose quartz.

Macon Co.—Franklin, Culsagee mine, *corundum*, spinel, diaspore, tourmaline, damourite, prochlorite, culsageeite, kerrite, maconite.

McDowell Co.—Brookite, monazite, corundum in small crystals, red and white, *zircons*, garnet, beryl, sphene, xenotime, rutile, elastic sandstone, iron ores, pyromelane, tetradymite, montanite.

Madison Co.—Twenty miles from Asheville, corundum, margarite, chlorite.

Mecklenburg Co.—Near Charlotte (Rhea and Cathay mines) and elsewhere, *chalcopyrite*, *gold;* chalcotrichite at McGinn's mine; barnhardtite near Charlotte; pyrophyllite in Cotton Stone Mountain, diamond; Flowe mine, scheelite, wolframite; Todd's Branch, *monazite*.

Mitchell Co.—At the Wiseman mica mine, *muscovite samarskite*, hatchettolite, euxenite, columbite, rogersite, *uraninite*, *gummite*, *uraconite*, torbernite, autunite; at Grassy Creek mine, *muscovite*, *samarskite*.

Montgomery Co.—Steele's mine, ripidolite, albite.

Moore Co.—Carbonton, compact pyrophyllite.

Rowan Co.—Gold Hill mines, thirty-eight miles northeast of Charlotte, and fourteen from Salisbury, gold, auriferous pyrite; ten miles from Salisbury, *feldspar* in crystals, *bismuthinite*.

Randolph Co.—Pyrophyllite.

Rutherford Co.—*Gold*, *graphite*, bismuthic gold, diamond, euclase, *pseudomorphous quartz?* chalcedony, corundum in small crystals, *epidote*, *pyrope*, brookite, zircon, monazite, rutherfordite, samarskite, *quartz crystals*, itacolumyte ; on the road to Cooper's Gap, cyanite.

Stokes and Surry Cos.—Iron ores, graphite.

Union Co.—Lemmond gold mine, eighteen miles from Concord (at Stewart's and Moore's mine), gold, quartz, blende, argentiferous galenite (containing 29·4 oz. of gold and 86·5 oz. of silver to the ton, Genth), pyrite, some chalcopyrite.

Yancey Co.—*Iron ores*, amianthus, *chromite*, garnet (spessartite), *samarskite*, *columbite*.

SOUTH CAROLINA.

Abbeville Dist.—Oakland Grove, *gold* (Dorn mine), galenite, pyromorphite, amethyst, garnet.

Anderson Dist.—At Pendleton, *actinolite*, galenite, kaolin, *tourmaline*.

Charleston.—*Selenite*.

Cheowee Valley.—Galenite, tourmaline, gold.

Chesterfield Dist.—Gold (Brewer's mine), talc, chlorite, pyrophyllite, pyrite, native bismuth, bismuth carbonate, red and yellow ochre, whetstone, enargite.

Darlington.—Kaolin.

Edgefield Dist.—Psilomelane.

Greenville Dist.—Galenite, pyromorphite, kaolin, chalcedony in buhrstone, beryl, plumbago, epidote, *tourmaline*.

Kershaw Dist.—*Rutile*.

Lancaster Dist.—Gold (Hale's mine), talc, chlorite, cyanite, itacolumyte, pyrite ; gold also at Blackman's mine, Massey's mine, Ezell's mine.

Laurens Dist.—Corundum, damourite.

Newberry Dist.—Leadhillite.

Pickens Dist.—Gold, manganese ores, kaolin.

Richland Dist.—Chiastolite, novaculite.

Spartanburg Dist.—*Magnetite*, chalcedony, *hematite ;* at the Cowpens, limonite, *graphite*, limestone, copperas ; Morgan mine, leadhillite, pyromorphite, cerussite.

Sumter Dist.—Agate.

Union Dist.—Fairforest gold mines, pyrite, chalcopyrite.

York Dist.—Limestones, whetstones, witherite, barite, tetradymite.

GEORGIA.

Burke and Scriven Cos.—Hyalite.

Cherokee Co.—At Canton Mine, chalcopyrite, galenite, clausthalite, plumbogummite, hitchcockite, *arsenopyrite*, lanthanite, *harrisite*, *cantonite*, pyromorphite, automolite, zinc, staurolite, cyanite ; at Ball-Ground, spodumene.

Clark Co., near Clarksville.—Gold, *xenotime*, zircon, rutile, cyanite, hematite, garnet, quartz.

Dade Co.—Halloysite, near Rising Fawn.

Fannin Co.—*Staurolite!* chalcopyrite.

HABERSHAM Co.—*Gold*, pyrite, chalcopyrite, *galenite*, hornblende, garnet, quartz, kaolinite, soapstone, chlorite, *rutile*, iron ores, tourmaline, staurolite, zircon.

HALL Co.—*Gold*, quartz, kaolin, diamond.

HANCOCK Co.—Agate, chalcedony.

HEARD Co.—*Molybdite*, quartz.

LEE Co.—At the Chewacla Lime Quarry, dolomite, barite, *quartz crystals*.

LINCOLN Co.—*Lazulite ! ! rutile ! !* hematite, cyanite, manaccanite, *pyrophyllite*, gold, itacolumyte rock.

LOWNDES Co.—Corundum.

LUMPKIN Co.—At Field's gold mine, near Dahlonega, *gold*, *tetradymite*, pyrrhotite, chlorite, menaccanite, allanite, apatite.

RABUN Co.—Gold, *chalcopyrite*.

SPAULDING Co.—Tetradymite.

WASHINGTON Co., near Saundersville.—*Wavellite*, *fire opal*.

ALABAMA.

BENTON Co.—Antimonial lead ore (boulangerite?)

BIBB Co., Centreville.—*Iron ores*, marble, *barite*, coal, cobalt.

CHAMBERS Co.—Near La Fayette, *steatite*, garnets, actinolite, *chlorite*; east of Oak Bowery, steatite.

CHILTON Co.—*Muscovite*, graphite, limonite.

CLEBURNE Co.—At Arbacoochee mine, gold, pyrite, and three miles distant cyanite, garnets; at Wood's mine, *black copper*, azurite, *chalcopyrite*, pyrite.

CLAY Co.—*Steatite*; near Delta and Ashland, *muscovite*.

COOSA Co.—Tantalite, gold, muscovite.

RANDOLPH Co.—Gold, pyrite, tourmaline, muscovite; at Louina, *porcelain clay*, garnet.

TALLADEGA Co.—*Limonite*.

TALLAPOOSA Co. at Dudleyville.—*Corundum*, margarite, ripidolite, spinel, tourmaline, actinolite, *steatite*, *asbestus*, chrysolite, damourite, corundum altered to tourmaline (crystals of the latter containing a nucleus of the former) and also other pseudomorphs, including, at Dudleyville, dudleyite.

TUSKALOOSA Co.—*Coal*, galenite, pyrite, vivianite, limonite, calcite, dolomite, cyanite, steatite, quartz crytals, manganese ores.

FLORIDA.

NEAR TAMPA BAY.—Limestone, sulphur springs, chalcedony, carnelian, agate, silicified shells and corals.

KENTUCKY.

ANDERSON Co.—Galenite, barite.

CLINTON Co.—Geodes of quartz.

CRITTENDEN Co.—Galenite, fluorite, calcite.

EDMONDSON Co.—At Mammoth Cave, *gypsum rosettes !* calcite, stalactites, nitre, epsomite.

Fayette Co.—Six miles N. E. of Lexington, galenite, barite, witherite, blende.

Livingston Co., near the line of Union Co.—Galenite, chalcopyrite, large vein of fluorite.

Mercer Co.—At McAfee, *fluorite*, *pyrite*, calcite, barite, celestite.

Owen Co.—Galenite, barite.

TENNESSEE.

Brown's Creek.—Galenite, blende, barite, celestite.

Carter Co., foot of Roan Mt.—*Sahlite*, magnetite.

Claiborne Co.—*Calamine*, galenite, smithsonite, chlorite, steatite, magnetite.

Cocke Co., near Bush Creek.—Cacoxenite? kraurite, iron sinter, stilpnosiderite, brown hematite.

Davidson Co.—Selenite, with granular and snowy *gypsum*, or alabaster, crystallized and compact *anhydrite*, *fluorite* in crystals? *calcite* in crystals. Near Nashville, blue *celestite* (crystallized, fibrous, and radiated), with *barite* in limestone. Haysboro', galenite, blende, with barite as the gangue of the ore.

Dickson Co.—Manganite.

Jefferson Co.—*Calamine*, galenite, fetid barite.

Knox Co.—Magnesian limestone, *native iron*, *variegated marbles!*

Maury Co.—Wavellite in limestone.

Morgan Co.—Epsom salt, nitrate of lime.

Polk Co., Ducktown mines, southeast corner of State.—Melaconite, chalcopyrite, pyrite, native copper, bornite, rutile, *zoisite*, galenite, *harrisite*, alisonite, blende, *pyroxene*, *tremolite*, *sulphates of copper and iron* in stalactites, allophane, rahtite, chalcocite (ducktownite), chalcotrichite, azurite, malachite, *pyrrhotite*, limonite.

Roan Co., easterly declivity of Cumberland Mts.—Wavellite in limestone.

Sevier Co., in caverns.—Epsomite, soda alum, nitre, nitrate of calcium, *breccia marble*.

Smith Co.—Fluorite.

Smoky Mt., on declivity.—Hornblende, garnet, staurolite.

White Co.—*Nitre*.

OHIO.

Bainbridge (Copperas Mt., a few miles east of B.).—Calcite, barite, pyrite, copperas, alum.

Canfield.—*Gypsum!*

Duck Creek, Monroe Co.—Petroleum.

Lake Erie.—Strontian Island, *celestite!* Put-in-Bay Island, *celestite! sulphur!* calcite.

Liverpool.—Petroleum.

Marietta.—Argillaceous iron ore · iron ore abundant also in Scioto and Lawrence Cos.

Ottawa Co.—Gypsum.

Poland.—*Gypsum!*

MICHIGAN.

Brest (Monroe Co.).—*Calcite*, amethystine quartz, apatite, celestite.

Grand Rapids.—*Selenite*, fib. and granular gypsum, *calcite*, *dolomite*, *anhydrite*.

Lake Superior Mining Region.—The four principal regions are Keweenaw Point, Isle Royale, the Ontonagon, and Portage Lake. The mines of Keweenaw Point are along two ranges of elevation, one known as the Greenstone Range, and the other as the Southern or Bohemian Range (Whitney). The copper occurs in the trap or amygdaloid, and in the associated conglomerate. *Native copper! native silver!* chalcopyrite, horn silver, tetrahedrite, manganese ores, epidote, *prehnite*, *laumontite*, *datolite*, heulandite, orthoclase, *analcite*, chabazite, compact datolite, chrysocolla, *mesotype* (Copper Falls mine), *leonhardite* (ib.), *analcite* (ib.), *apophyllite* (at Cliff mine), *wollastonite* (ib.), calcite, *quartz* (in crystals at Minnesota mine), compact datolite, orthoclase (Superior mine), *saponite*, melaconite (near Copper Harbor, but exhausted), chrysocolla; on Chocolate River, galenite and sulphide of copper; chalcopyrite and native copper at Presq'Isle; at Albion mine, *domeykite*; at Prince Vein, *barite*, *calcite amethyst*; at Albany and Boston mine, Portage Lake, *prehnite*, *analcite*, *orthoclase*, cuprite; at Sheldon location, *domeykite*, *whitneyite*, *algodonite*; Quincy mine, calcite, compact datolite. At the Spur Mountain iron mine (magnetite), chlorite pseudomorph after garnet; Isle Royale, datolite, prehnite.

Marquette.—Manganite, galenite; twelve miles west at Jackson Mt., and other mines, *hematite*, *limonite*, *göthite!* magnetite, jasper.

Monroe.—Aragonite, apatite.

Point aux Peaux (Monroe Co.)—*Amethystine quartz*, *apatite*, celestite, *calcite*.

Saginaw Bay.—At Alabaster, *gypsum*.

Stony Point (Monroe Co.)—Apatite, amethystine quartz, celestite, calcite.

ILLINOIS.

Gallatin Co., on a branch of Grand Pierre Creek, sixteen to thirty miles from Shawneetown, down the Ohio, and from half to eight miles from this river.—*Violet fluorite!* in carboniferous limestone, barite, *galenite*, blende, brown iron ore.

Hancock Co.—At Warsaw, *quartz geodes* containing *calcite! chalcedony*, *dolomite*, *blende!* brown spar, pyrite, aragonite, gypsum, bitumen.

Hardin Co.—Near Rosiclare, *calcite*, galenite, blende; five miles back from Elizabethtown, bog iron; one mile north of the river, between Elizabethtown and Rosiclare, *nitre*.

Jo Daviess Co.—At Galena, *galenite*, calcite, *pyrite*, blende; at Marsden's diggings, *galenite! blende*, *cerussite*, marcasite in stalactitic forms, pyrite.

Joliet.—*Marble*.

Quincy.—*Calcite!* pyrite.

Scales Mound.—*Barite*, pyrite.

INDIANA.

Limestone Caverns; Corydon Caves, etc.—*Epsom salt.*

In most of the southwest counties, *pyrite*, *iron sulphate*, and *feather alum;* on Sugar Creek, pyrite and *iron sulphate;* in sandstone of Lloyd Co., near the Ohio, *gypsum;* at the top of the blue limestone formation, brown *spar*, *calcite.*

Lawrence Co.—Spice Valle, kaolinite (=indianaite).

MINNESOTA.

North Shore of L. Superior (range of hills running nearly north east and southwest, extending from Fond du Lac Superieure to the Kamanistiqueia River in Upper Canada).—*Scolecite*, *apophyllite*, *prehnite*, *stilbite*, *laumontite*, *heulandite*, *harmotome*, thomsonite, *fluorite*, *barite*, *tourmaline*, *epidote*, hornblende, calcite, quartz crystals, pyrite, magnetite, steatite, blende, black oxide of copper, malachite, native copper, chalcopyrite, amethystine quartz, ferruginous quartz, *chalcedony*, *carnelian*, *agate*, drusy quartz, hyalite? fibrous quartz, jasper, prase (in the debris of the lake shore), dogtooth spar, augite, native silver, spodumene? chlorite; between Pigeon Point and Fond du Lac, near Baptism River, saponite (thalite) in amygdaloid.

Kettle River Trap Range.—Epidote, nail-head calcite, amethystine quartz, calcite, undetermined zeolites, saponite.

Stillwater.—Blende.

Falls of the St. Croix.—Malachite, native copper, epidote, nail-head spar (calcite).

Rainy Lake.—Actinolite, tremolite, fibrous hornblende, garnet, pyrite, magnetite, steatite.

WISCONSIN.

Big Bull Falls (near).—Bog iron.

Blue Mounds.—Cerussite.

Hazel Green.—Calcite.

Lac du Flambeau R.—Garnet, cyanite.

Left-Hand R. (near small tributary).—Malachite, chalcocite, native copper, cuprite, malachite, epidote, chlorite? quartz crystals.

Linden.—*Galenite*, *smithsonite*, *hydrozincite.*

Mineral Point and vicinity.—Copper and lead ores, chrysocolla, *azurite!* chalcopyrite, malachite, *galenite*. cerussite, anglesite, blende, *pyrite*, barite, *calcite*, *marcasite*, *smithsonite!* (including pseudomorphs after calcite and blende), (so-called "dry-bone"), calamine, bornite, hydrozincite.

Montreal River Portage.—Galenite in gneissoid granite.

Sauk Co.—Hematite, malachite, chalcopyrite.

Shullsburg.—*Galenite!* blende, pyrite; at Emmet's digging, *galenite* and pyrite.

IOWA.

Du Buque Lead Mines, and elsewhere.—*Galenite!* *calcite*, *blende*, black oxide of manganese; at Ewing's and Sherard's diggings, *smith-*

sonite, calamine ; at Des Moines, quartz crystals, selenite ; Makoqueta R., limonite ; near Durango, galenite.

Cedar River, a branch of the Des Moines.—*Selenite* in crystals, in the bituminous shale of the coal measures ; also elsewhere on the Des Moines, gypsum abundant ; argillaceous iron ore, spathic iron ; copperas in crystals on the Des Moines, above the mouth of Saap and elsewhere, *pyrite*, blende.

Fort Dodge.—*Celestite.*

Makoqueta.—Hematite.

New Galena.—Octahedral galenite, anglesite.

MISSOURI.

For the distribution of the lead mines see page 147. The number of minerals associated with the lead ore varies greatly in the different lead regions. Mine la Motte, and some old openings in Madison Co., are peculiar in affording cobalt and nickel ores abundantly. At Granby and other mines the chief zinc ore is calamine, or the silicate of zinc, while in the mines of Central and Southwest Missouri it is comparatively rare, and smithsonite is the prominent ore—as is the case in Wisconsin ; yet calamine is the most abundant zinc ore in the State. As stated by A. Schmidt, the zinc ore, in each case, is found as a secondary product to sphalerite (blende) ; the cerussite often coats the galenite, or has its forms, indicating thus its source ; the limonite is also secondary, and has come in mainly through the oxidation of pyrite. At the Granby mines, the calamine is called, among the miners, "Black Jack ;" blende, "Resin Jack ;" a white massive smithsonite, "White Jack ;" and the cerussite is the "Dry Bone ;" thus departing from ordinary miners' usage. Gold has been found in the drift sands of Northern Missouri (Broadhead).

Adair Co.—Göthite in calcite.

Barton Co.—Pickeringite as an efflorescence on sandstone.

Chariton Co.—Near Salisbury, *gypsum* (selenite) in coal beds.

Cole Co.—At Old Circle Diggings and elsewhere, *barite!* galenite, chalcopyrite, malachite, azurite, pyrite, calcite, calamine, sphalerite.

Cooper Co.—Collins Mine, *malachite* with azurite, etc.

Dade Co.—*Smithsonite.*

Franklin Co.—Cove Mines, *anglesite, galenite, cerussite*, barite.

Iron Co.—At Pilot Knob and Shepherd Mountain, *hematite*, magnetite, *limonite*, manganese oxide, bog manganese.

Jasper Co. (adjoins S. E. Kansas).—At Joplin Mines, *galena! sphalerite*, pyrite, *cerussite*, calamine, dolomite, bitumen.

Jefferson Co.—At Valle's, *galenite! cerussite, anglesite, calamine, smithsonite*, sphalerite, hydrozincite, chalcopyrite, malachite, azurite, pyrite, *barite*, witherite, limonite. At Frumet mines, 8½ miles from De Soto R. R. station, galena, *barite! smithsonite!* pyrite, limnite.

Madison Co.—At Mine la Motte, *galenite! cerussite! siegenite* (nickel-linnæite), smaltite, *asbolite* (earthy black cobalt ore), bog manganese, *chalcopyrite*, malachite, caledonite, plumbogummite, wolframite.

Morgan Co.—At Cordray Diggings, *galena*, blende, *barite.*

Newton Co. (adjoins S. E. Kansas).—At Granby Mines, *galenite! cerussite, calamine! sphalerite, smithsonite, hydrozincite, greenockite* (on sphalerite), pyromorphite, dolomite, calcite, bitumen, *buratite.*

St. Francois Co.—Iron Mountain, hematite, magnetite, limonite.

St. Louis Co.—Near St. Louis, *millerite* (in the Subcarboniferous St. Louis limestone, largely a magnesian limestone) with *calcite!* barite, *fluorite*.

Washington Co.—At Potosi, *galenite, cerussite*, anglesite, barite.

ARKANSAS.

Batesville.—In bed of White R., some miles above Batesville, gold.

Green Co.—Near Gainesville, lignite.

Hot Springs Co.—At Hot Springs, *wavellite*, thuringite; Magnet Cove, *brookite! schorlomite, elæolite*, magnetite, quartz, green coccolite, *garnet*, apatite, *perofskite* (hydrotitanite), *rutile*, ripidolite, thomsonite (ozarkite), *microcline, ægirite*, protovermiculite.

Independence Co.—Lafferay Creek, psilomelane.

Lawrence Co.—Hoppe, Bath, and Koch mines, *smithsonite*, dolomite, galenite; nitre.

Marion Co.—Wood's mine, smithsonite, hydrozincite (marionite) galenite; Poke bayou, *braunite?*

Montgomery Co.—Variscite.

Ouachita Springs.—*Quartz?* whetstones.

Pulaski Co.—Kellogg mine, 10 m. north of Little Rock, *tetrahedrite, tennantite*, nacrite, galenite, blende, quartz.

CALIFORNIA.

The principal *gold mines* of California are in Tulare, Fresno, Mariposa, Tuolumne, Calaveras, El Dorado, Placer, Nevada, Yuba, Sierra, Butte, Plumas, Shasta, Siskiyou, and Del Norte counties, although gold is found in almost every county of the State. The gold occurs in quartz, associated with sulphides of iron, copper, zinc, and lead; in Calaveras and Tuolumne counties, at the Mellones, Stanislaus, Golden Rule, and Rawhide mines, associated with tellurides of gold and silver; it is also largely obtained from placer diggings, and further it is found in beach washings in Del Norte and Klamath counties.

The *copper mines* are principally at or near Copperopolis, in Calaveras County; near Genesee Valley, in Plumas County; near Low Divide, in Del Norte County; on the north fork of Smith's River; at Soledad, in Los Angeles county.

The *mercury mines* are at or near New Almaden and North Almaden, in Santa Clara County; at New Idria and San Carlos, Monterey County; in San Luis Obispo County; at Pioneer mine, and other localities in Lake County; in Santa Barbara County.

Alameda Co.—Diabolo Range, magnesite.

Alpine Co.—Morning Star mine, *enargite*, stephanite, polybasite, barite, quartz, pyrite, tetrahedite, pyrargyrite.

Amador Co.—At Volcano, chalcedony, *hyalite;* Lone Valley, lonite; Fiddletown, diamond.

Butte Co.—Cherokee Flat, diamond, platinum, iridosmine.

Calaveras Co.—Copperopolis, *chalcopyrite*, malachite, *azurite, serpentine, picrolite*, native copper; near Murphy's, jasper, opal; albite, with gold and pyrite; Mellones mine, *calaverite, petzite*.

Contra-Costa Co.—San Antonio, chalcedony.

Del Norte Co.—Crescent City, agate, carnelian; Low Divide, chalcopyrite, bornite, malachite; on the coast, iridosmine, platinum, gold, zircon, diamond.

El Dorado Co.—Pilot Hill, chalcopyrite; near Georgetown, hessite, from placer diggings; Roger's Claim, Hope Valley, *grossular garnet*, in copper ore; Coloma, *chromite;* Spanish Dry Diggings, *gold;* Granite Creek, roscoelite, gold; Forest Hill, diamond; Cosumnes mine, molybdenite.

Fresno Co.—Chowchillas, *andalusite;* King's River, bornite.

Humboldt Co.—Cryptomorphite.

Inyo Co.—Inyo district, *galenite, cerussite, anglesite, barite,* atacamite, calcite, *grossular garnet!* Surprise Mine, tetrahedrite; Kearsarge mine, silver ores; Cerro Gordo, wulfenite.

Kern Co.—Green Monster mine, cuproscheelite.

Lake Co.—Borax Lake, *borax!* sassolite, *glauberite;* Pioneer mine, cinnabar, native mercury, selenide of mercury; near the Geysers, sulphur, hyalite; Redington mine, metacinnabarite; Lower Lake, chromite.

Los Angeles Co.—Near Santa Anna River, *anhydrite;* Williams Pass, chalcedony; Soledad mines, chalcopyrite, *garnet,* gypsum; Mountain Meadows, garnet, in copper ore.

Mariposa Co.—Chalcopyrite, itacolumyte; Centreville, cinnabar; Pine Tree mine, tetrahedrite; Burns Creek, limonite; Geyer Gulch, pyrophyllite; La Victoria mine, *azurite!* near Coulterville, *cinnabar, gold.*

Mono Co.—Partzite (stibiconite).

Monterey Co.—Alisal mine, arsenic; near Paneches, chalcedony; New Idria mine, cinnabar; near New Idria, chromite, zaratite, chrome garnet; near Pacheco's Pass, stibnite.

Napa Co.—Chromite.

Nevada Co.—Grass Valley, *gold!* in quartz veins, with pyrite, chalcopyrite, blende, arsenopyrite, galenite, *quartz,* biotite; near Truckee Pass, gypsum; Excelsior Mine, molybdenite, with gold; Sweet Land, pyrolusite.

Placer Co.—Miner's Ravine, *epidote!* with *quartz, gold.*

Plumas Co.—Genesee Valley, chalcopyrite; Hope mines, *bornite,* sulphur.

Santa Barbara Co.—San Amedio Cañon, stibnite, asphaltum, bitumen, maltha, petroleum, cinnabar, iodide of mercury; Santa Clara River, sulphur.

San Bernardino Co.—Colorado River, agate, trona; Temescal Mts., cassiterite; Russ District, galenite, cerussite; Francis mine, cerargyrite; Slate Range, thenardite, borax, common salt; San Bernardino Mts., graphites.

Santa Clara Co.—New Almaden, *cinnabar, calcite, aragonite,* serpentine, chrysolite, quartz, aragotite; North Almaden, chromite; Mt. Diabolo Range, magnesite, datolite, with vesuvianite and garnet.

San Diego Co.—Carisso Creek, gypsum; San Isabel, tourmaline orthoclase, garnet.

San Francisco Co.—Red Island, pyrolusite and manganese ores.

San Luis Obispo Co.—Asphaltum, cinnabar, native mercury, chromite.

SHASTA Co.—Near Shasta City, hematite, in large masses.

SIERRA Co.—Forest City, gold, arsenopyrite, tellurides.

SISKIYOU Co.—Surprise Valley, selenite, in large slabs.

SONOMA Co.—Actinolite, garnets, chromite, serpentine.

TULARE Co.—Near Visalia, magnesite, asphaltum.

TUOLUMNE Co.—Tourmaline, tremolite; Sonora, *graphite;* York Tent, chromite; Golden Rule mine, *petzite*, *calaverite*, altaite, hessite, magnesite, tetrahedrite, gold; Whiskey Hill, *gold!*

TRINITY Co.—Cassiterite, a single specimen found.

LOWER CALIFORNIA.

LA PAZ.—Cuproscheelite. **LORETTO.**—Natrolite, siderite, selenite.

UTAH.

BEAVER Co.—Bismuthinite, bismite, bismutite.

TINTIC DISTRICT.—At the Shoebridge mine, the Dragon mine, and the Mammoth vein, *enargite* with pyrite.

BOX ELDER Co.—Empire mine, *wulfenite!*

UTAH Co.—Ammonia alum.

In the Wahsatch and Oquirrh mountains there are extensive mines, especially of ores of lead rich in silver. At the Emma mine occur galenite, cervantite, cerussite, wulfenite, azurite, malachite, calamine, anglesite, linarite, sphalerite, pyrite, argentite, stephanite, etc. At the Lucky Boy mine, Butterfield Cañon, orpiment, realgar.

One hundred and twenty miles southwest of Salt Lake City, *topaz* has been found in colorless crystals. At a silver mine, fibrous sepiolite.

NEVADA.

CARSON VALLEY.—Chrysolite.

CHURCHILL Co.—Near Ragtown, *gay-lussite*, trona, common salt.

COMSTOCK LODE.—Gold, *native silver*, *argentite*, *stephanite*, *polybasite*, pyrargyrite, proustite, tetrahedrite, cerargyrite, pyrite, chalcopyrite, galenite, blende, pyromorphite, allemontite, arsenolite, quartz, calcite, gypsum, cerussite, cuprite, wulfenite, amethyst, küstelite.

ELKO Co.—Emma Mine, chrysocolla.

ESMERALDA Co.—Alum, 12 m. north of Silver Creek; at Aurora, fluorite, stibnite; near Mono Lake, native copper and cuprite, obsidian; Thiel Salt Marsh, ulexite, borax, common salt, thenardite; Columbus district, ulexite, thenardite, sulphur; Walker Lake, gypsum, hematite; Silver Peak, *salt*, saltpetre, sulphur, silver ores.

HUMBOLDT DISTRICT.—Sheba mine, *native silver*, *jamesonite*, stibnite, *tetrahedrite*, proustite, blende, cerussite, calcite, bournonite, pyrite, galenite, malachite, xanthocone (?), cuprite.

LANDER Co.—Austin, polybasite, chalcopyrite, azurite.

LINCOLN Co.—Rock salt, cerargyrite.

MAMMOTH DISTRICT.—*Orthoclase*, turquoise, *hübnerite*, scheelite.

NYE Co.—Anglesite, stetefeldite, azurite, cerussite, silver ores, cerargyrite.

REESE RIVER DISTRICT.—Native silver, *proustite*, *pyrargyrite*, stephanite, blende, polybasite, rhodochrosite, embolite, *tetrahedrite!* cerargyrite, embolite.

SAN ANTONIA.—Belmont mine, stetefeldtite.

SIX-MILE CAÑON.—*Selenite*.

ORMSBY CO.—W. of Carson, *epidote*.

STOREY CO.—Alum, natrolite, scolecite.

WHITE PINE CO.—Eberhardt mine, cerargyrite; Paymaster mine, freieslebenite.

ARIZONA

To the south, south of Tucson, near the Mexican boundary, the region about Tubac Arivaca, the Santa Rita and the Patagonia Mts., noted for silver mines, the ore in part *argentiferous galenite;* about Tucson, copper ores; a little to the north, the Heintzelmann mine, *Stromeyerite*, chalcocite, *tetrahedrite*, native silver, atacamite; on and near the Colorado River, in Yuma County, the Castle Dome, Eureka and other mines, of gold, silver, and copper, *argentiferous galenite* the prominent silver ore. In the Penal range, gold; on the San Francisco River, native copper, covellite, chalcopyrite, malachite, azurite; at Bill Williams Fork, malachite, chrysocolla, atacamite, brochantite; Montgomery mine, Harsayampa district, tetradymite.

North of the Gila, just west of the boundary of New Mexico, *chalcocite, cuprite, malachite.*

OREGON AND WASHINGTON.

Gold is obtained from beach washings on the southern coast; quartz mines and placer mines in the Josephine district; also on the Powder, Burnt, and John Day's rivers, and other places in Eastern Oregon; platinum, iridosmine, laurite, on the Rogue River, at Port Orford, and Cape Blanco. In Curry Co., *priceite*.

At Seattle, Washington T.—Scheelite, tourmaline; at Fidalgo, realgar.

IDAHO.

In the Owyhee, Boise, and Flint districts, *gold*, also extensive silver mines; Poor Man's Lode, *cerargyrite! proustite, pyrargyrite! native silver, gold*, pyromorphite, quartz, malachite, stephanite; polybasite; on Jordan Creek, stream tin; Rising Star mine, *stephanite, argentite*, pyrargyrite; Charity mine, Warren's, *scheelite, gold.*

MONTANA.

Many mines of gold, etc., west of the Missouri River. HIGHLAND DISTRICT.—Tetradymite. SILVER STAR DIST.—Psittacinite.

In the Yellowstone Park, in Montana and Wyoming Territories.—*Geyserite, amethyst! chalcedony*, quartz crystals, quartz on calcite, etc.

COLORADO.

The principal gold mines of Colorado are in Boulder, Gilpin, Clear Creek, and Jefferson Counties, on a line of country a few miles W. of Denver, extending from Long's Peak to Pike's Peak. A large portion of the gold is associated with veins of pyrite and chalcopyrite ; silver and lead mines are at and near Georgetown, Clear Creek County, and to the westward in Summit County, on Snake and Swan rivers.

At the GEORGETOWN mines are found :—native silver, pyrargyrite, argentite, tetrahedrite, pyromorphite, galenite, sphalerite, azurite, aragonite, barite, fluorite, mica.

TRAIL CREEK.—Garnet, epidote, hornblende, chlorite ; at the Freeland Lode, *tetrahedrite*, tennantite, anglesite, caledonite, cerussite, tenorite, siderite, azurite, minium ; at the Champion Lode, tenorite, azurite, chrysocolla, malachite ; at the Gold Belt Lode, vivianite ; at the Kelly Lode, tenorite ; at the Coyote Lode, malachite, cyanotrichite.

Near BLACK HAWK.—At Willis Gulch, enargite, fluorite, pyrite ; at the Gilpin County Lode, cerargyrite ; on Gregory Hill, feldspar ; North Clear Creek, lievrite.—*Galenite!*

BEAR CREEK.—Fluorite, beryl ; near the Malachite Lode, *malachite*, *cuprite*, vesuvianite, topazolite ; Liberty Lode, chalcocite.

SNAKE RIVER.—Penn District, embolite ; at several lodes, pyrargyrite, native silver, azurite.

RUSSELL DISTRICT.—Delaware Lode, *chalcopyrite*, crystallized *galenite*.—Epidote, pyrite.

VIRGINIA CAÑON.—Epidote, fluorite ; at the Crystal Lode, native silver, spinel.

SUGAR LOAF DISTRICT.—Chalcocite, pyrrhotite, garnet (manganesian).

CENTRAL CITY.—Garnet, tenorite ; at Leavitt Lode, molybdenite ; on Gunnell Hill, magnetite ; at the Pleasantview mine, cerussite.

GOLDEN CITY.—Aragonite ; on Table Mountain, leucite in amygdaloid.

BERGEN'S RANCHE.—Garnet, actinolite, calcite.

BOULDER CO.—Red Cloud Mine : Native tellurium, altaite, hessite (petzite), sylvanite, calaverite, schirmerite. Keystone Mine : Coloradoite, magnolite, ferotellurite, tellurite, roscoelite ? also part of these at Smuggler mine and Mountain Lion mine. Grand View mine : sylvanite, etc.

LAKE CITY, at the Hotchkiss Lode.—Petzite, calaverite (?), etc.

LAKE CO., Golden Queen mine.—*Scheelite*, gold.

PIKE'S PEAK, on Elk Creek.—*Amazon-stone ! ! smoky quartz ! aventurine feldspar*, amethyst, *albite*, fluorite, hematite, anhydrite (rare), columbite.

SAN JUAN DISTRICT.—Gold, sphalerite, pyrite, galenite, chalcocite, covellite, chalcopyrite.

CANADA EAST.

ABERCROMBIE.—Labradorite.

AUBERT.—Gold, iridosmine, platinum.

BAIE ST. PAUL.—*Menaccanite !* apatite, allanite, rutile.

Bolton.—*Chromite*, *magnesite*, serpentine, picrolite, *steatite*, bitter spar, wad, rutile.

Boucherville.—*Augite* in trap.

Brome.—*Magnetite*, chalcopyrite, *sphene*, menaccanite, phyllite, sodalite, cancrinite, galenite, chloritoid, rutile.

Broughton.—Serpentine, steatite.

Chambly.—Analcite, chabazite and calcite in trachyte, *menaccanite*.

Chateau Richer.—*Labradorite*, *hypersthene*, andesite.

Daillebout.—Blue spinel with clintonite.

Grenville.—Wollastonite, *sphene*, *muscovite*, vesuvianite, calcite, pyroxene, serpentine, steatite (rensselaerite), chondrodite, *garnet* (cinnamon-stone), *zircon*, *graphite*, *scapolite*.

Fitzroy.—Graphite.

Ham.—Chromite in serpentine, diallage, *antimony! senarmontite! kermesite*, *valentinite*, stibnite.

Hunterstown.—*Scapolite*, *sphene*, vesuvianite, garnet, *brown tourmaline!*

Inverness.—Bornite, chalcocite, pyrite.

Lake St. Francis.—*Andalusite* in mica slate.

Leeds.—Dolomite, chalcopyrite, gold, *chloritoid*, chalcocite, bornite, pyrite, *steatite*.

Mille Isles.—*Labradorite!* menaccanite, hypersthene, andesite, *zircon*.

Montreal.—*Calcite*, *augite*, sphene in trap, chrysolite, natrolite, dawsonite.

Morin.—*Sphene*, *apatite*, *labradorite*.

Orford.—White garnet, *chrome garnet*, *millerite*, *serpentine*.

Ottawa.—*Pyroxene*.

Portage de Fort.—Rensselaerite.

Potton.—Chromite, *steatite*, serpentine, *amianthus*.

Rougemont.—Augite in trap.

St. Armand.—Micaceous iron ore with quartz, epidote.

St. Francois Beauce.—Gold, platinum, iridosmine, menaccanite, magnetite, serpentine, chromite, soapstone, barite.

St. Jerome.—*Sphene*, *apatite*, *chondrodite*, *phlogopite*, *tourmaline*, *zircon*, *garnet*, molybdenite, pyrrhotite, wollastonite, *labradorite*.

St. Norbert.—Amethyst in greenstone.

Sherbrook.—At Suffield mine, *albite! native silver*, argentite, chalcopyrite, blende.

South-Crosby.—Chondrodite.

Stukeley.—Serpentine, *verd-antique!* schiller spar.

Sutton.—*Magnetite*, in fine crystals, hematite, *rutile*, dolomite, *magnesite*, chromiferous *talc*, bitter spar, steatite.

Upton.—Chalcopyrite, malachite, calcite.

Vaudreuil.—Limonite, vivianite.

Yamaska.—Sphene in trap.

CANADA WEST.

Arnprior.—Calcite.

Balsam Lake.—*Molybdenite*, scapolite, quartz, pyroxene, pyrite.

Bathurst.—Barite, *black tourmaline*, *perthite* (orthoclase), *peristerite* (albite), *bytownite*, pyroxene, wilsonite, scapolite, apatite, titanite.

Brantford.—Sulphuric acid spring (4·2 parts of pure sulphuric acid in 1,000).

Brockville.—Pyrite.

Brome.—Magnetite.

Bruce Mines on Lake Huron.—*Calcite,* dolomite, quartz, *chalcopyrite, chalcocite.*

Burgess.—*Pyroxene,* albite, *mica,* corundum, sphene, chalcopyrite, *apatite, black spinel!* spodumene (in a boulder), serpentine, biotite.

Bytown.—*Calcite, bytownite,* chondrodite, spinel.

Cape Ipperwash, Lake Huron.—Oxalite in shales.

Chaudiere Valley.—Gold, sphalerite, pyrite, pyrrhotite, galenite.

Clarendon.—*Vesuvianite, tourmaline.*

Dalhousie.—Hornblende, dolomite.

Drummond.—Labradorite.

Elizabethtown.—*Pyrrhotite, pyrite,* calcite, magnetite, talc, phlogopite, siderite, apatite, cacoxenite.

Elmsley.—Pyroxene, sphene, feldspar, *tourmaline,* apatite, biotite, zircon, red spinel, chondrodite.

Fitzroy.—Amber, brown *tourmaline,* in quartz.

Gatineau River, Blasdell's Mills.—Calcite, apatite, tourmaline, hornblende, pyroxene.

Grand Calumet Island.—*Apatite phlogopite! pyroxene!* hornblende, sphene, *vesuvianite!!* serpentine, tremolite, *scapolite,* brown and black *tourmaline!* pyrite, loganite.

High Falls of the Madawaska.—*Pyroxene!* hornblende.

Hull.—*Magnetite,* garnet, graphite.

Huntington.—*Calcite!*

Inniskillen.—Petroleum.

Kingston.—*Celestite.*

Lac des Chats, Island Portage.—*Brown tourmaline!* pyrite, calcite, quartz.

Lanark.—Raphilite (hornblende), serpentine, asbestus, perthite (aventurine feldspar), peristerite.

Lansdowne.—*Barite!* vein 27 in. wide, and fine crystals, rensselaerite, sphalerite, wilsonite, labradorite.

Madoc.—Magnetite.

Marmora.—Magnetite, chalcolite, serpentine, garnet, epsomite, specular iron, steatite.

McNab.—Hematite, barite.

Michipicoton Island, Lake Superior.—*Domeykite, nicolite, genthite, chalcopyrite,* native copper, native silver, chalcocite, galenite, amethyst, calcite, stilbite, analcite. At Maimanse Bay: Coracite, chalcocite, chalcopyrite, native copper.

Newborough.—*Chondrodite,* graphite.

Pakenham.—Hornblende.

Perth.—Apatite in large beds, phlogopite.

St. Adele.—Chondrodite in limestone.

St. Ignace Island.—*Calcite,* native copper.

Silver Id., Lake Superior.—Argentite, native silver, galenite, niccolite, chalcocite, malachite.

Sydenham.—Celestite.

Terrace Cove, Lake Superior.—Molybdenite.

Wallace Mine, Lake Huron.—Hematite, nickel ore, nickel vitriol, *chalcopyrite.*

NEW BRUNSWICK.

ALBERT CO.—Hopewell, gypsum; Albert mines, coal (albertite); Shepody Mountain, alunite in clay, calcite, pyrite, *manganite*, psilomelane, *pyrolusite*.

CARLETON CO. — Woodstock, chalcopyrite, hematite, limonite, wad.

CHARLOTTE CO.—Campobello, at Welchpool, blende, chalcopyrite, bornite, galenite. pyrite; at head of Harbor de Lute, galenite; Deer Island, on west side, calcite, magnetite, quartz crystals; Digdighash River on west side of entrance, *calcite!* (in conglomerate), chalcedony; at Rolling Dam, graphite; Grandmanan, between Northern Head and Dark Harbor, agate, amethyst, *apophyllite*, *calcite*, hematite, heulandite, jasper, magnetite, natrolite, *stilbite*; at Whale Cove, *calcite!* heulandite, laumontite, stilbite, *semi-opal!*; Wagaguadavic River, at entrance, azurite, chalcopyrite in veins, malachite.

GLOUCESTER CO.—Tete-a-Gouche River, eight miles from Bathurst, chalcopyrite (mined), *oxide of manganese!!* formerly mined.

KINGS CO.—Sussex, near Cloat's mills, on road to Belleisle, argentiferous galenite; one mile north of Baxter's Inn, *specular iron* in crystals, limonite; on Capt. McCready's farm, *selenite!!*

RESTIGOUCHE CO.—Belledune Point, *calcite! serpentine*, *verd-antique*; Dalhousie, agate, carnelian.

ST. JOHN CO.—Black River, on coast, calcite, chlorite, chalcopyrite, *hematite!* Brandy Brook. epidote, *hornblende*, quartz crystals; Carleton, near Falls, calcite; Chance Harbor, *calcite* in quartz veins, chlorite in argillaceous and talcose slate; Little Dipper Harbor, on west side, in greenstone. amethyst, barite, quartz crystals; Moosepath, feldspar, hornblende, muscovite, black tourmaline; Musquash, on east side harbor, copperas, graphite, pyrite; at Shannon's, chrysolite, serpentine; east side of Musquash, *quartz crystals!*; Portland at the Falls, graphite; at Fort Howe Hill, *calcite*, graphite; Crow's Nest, asbestus, *chrysolite*, magnetite, *serpentine*, steatite; Lily Lake, white augite? chrysolite, graphite, serpentine, steatite talc; How's Road, two miles out, epidote (in syenite), steatite in limestone, *tremolite*; Drury's Cove, graphite, pyrite, pyrallolite? indurated talc; Quaco, at Lighthouse Point, large bed oxide of manganese; Sheldon's Point, actinolite, asbestus, calcite, *epidote*, malachite, specular iron; Cape Spenser, asbestus, calcite, chlorite, *specular iron* (in crystals); Westbeach, at east end on Evans's Farm, chlorite, talc, *quartz crystals*; half a mile west, chlorite, chalcopyrite, magnesite (vein), magnetite; Point Wolf and Salmon River, asbestus, chlorite, chrysocolla, chalcopyrite, bornite, pyrite.

VICTORIA CO.—Tabique River. *agate*, *carnelian*, jasper; at mouth, south side, galenite; at mouth of Wapskanegan, gypsum, salt spring; three miles above, stalactites (abundant); Quisabis River, blue phosphate of iron, in clay.

WESTMORELAND CO.—Bellevue, pyrite; Dorchester, on Taylor's Farm, cannel coal; clay ironstone; on Ayres's Farm, asphaltum, petroleum spring; Grandlance, apatite, selenite (in large crystals); Memramcook, coal (albertite); Shediac, four miles up Scadoue River, coal.

YORK CO. — Near Fredericton, stibnite, jamesonite, berthierite; Pokiock River, stibnite, *tin pyrites?* in granite (rare).

NOVA SCOTIA.

ANNAPOLIS Co.—Chute's Cove, *apophyllite*, natrolite ; Gates's Mountain, analcite, magnetite, *mesolite ! natrolite*, stilbite ; Martial's Cove, *analcite !* chabazite, *heulandite ;* Moose River, beds of magnetite ; Nictau River, at the Falls, bed of hematite ; Paradise River, black tourmaline, *smoky quartz !!;* Port George, faröelite, laumontite, mesolite, stilbite ; east of Port George, on coast, apophyllite containing gyrolite ; Peter's Point, west side of Stonock's Brook, *apophyllite !* calcite, heulandite, *laumontite !* (abundant), native copper, stilbite ; St. Croix's Cove, chabazite, heulandite.

COLCHESTER Co.—Five Islands, East River, *barite !* calcite, dolomite (ankerite), hematite, chalcopyrite ; Indian Point, malachite, magnetite, red copper, tetrahedrite ; Pinnacle Islands, *analcite*, calcite, *chabazite !* natrolite, siliceous sinter ; Londonderry, on branch of Great Village River, *barite*, ankerite, hematite, limonite, magnetite ; Cook's Brook, ankerite, hematite ; Martin's Brook, hematite, limonite ; at Folly River, below Falls, ankerite, pyrite ; on high land, east of river, ankerite, hematite, limonite ; on Archibald's land, ankerite, *barite*, hematite ; Salmon River, south branch of, chalcopyrite, hematite ; Shubenacadie River, anhydrite, calcite, *barite*, hematite, oxide of manganese ; at the Canal, pyrite ; Stewiacke River, barite (in limestone).

CUMBERLAND Co.—Cape Chiegnecto, barite ; Cape d'Or, *analcite, apophyllite !!* chabazite, faröelite, laumontite, *mesolite*, malachite, *natrolite, native copper*, obsidian, red copper (rare), vivianite (rare) ; Horse Shoe Cove, east side of Cape d'Or, analcite, calcite, stilbite ; Isle Haute, south side, analcite, *apophyllite !!* calcite, *heulandite !!* natrolite, mesolite, *stilbite !;* Joggins, coal, hematite, limonite ; malachite and tetrahedrite at Seaman's Brook ; Partridge Island, analcite, *apophyllite !* (rare), *amethyst !* agate, apatite (rare), *calcite !!* chabazite (acadialite), chalcedony, cat's eye (rare), gypsum, hematite, *heulandite !* magnetite, *stilbite !!;* Swan's Creek, west side, near the Point, calcite, gypsum, *heulandite*, pyrite ; east side, at Wasson's Bluff and vicinity, *analcite !! apophyllite !* (rare), *calcite, chabazite !!* (acadialite), gypsum, *heulandite !! natrolite !* siliceous sinter ; Two Islands, moss agate, analcite, calcite, chabazite, *heulandite ;* McKay's Head, analcite, calcite, heulandite, *siliceous sinter !*

DIGBY Co. — Briar Island, native copper, in trap ; Digby Neck, Sandy Cove and vicinity, *agate; amethyst, calcite, chabazite, hematite ! laumontite* (abundant), magnetite, *stilbite*, quartz crystals ; Gulliver's Hole, *magnetite, stilbite ! ;* Mink Cove, amethyst, *chabazite !* quartz crystals ; Nichols Mountain, south side, *amethyst, magnetite !;* Williams Brook, near source, *chabazite* (green), heulandite, stilbite, quartz crystal.

GUYSBORO' Co.—Cape Canseau, *andalusite*.

HALIFAX Co.—Gay's River, galenite in limestone ; southwest of Halifax, garnet, staurolite, tourmaline ; Tangier, *gold !* in quartz veins in clay slate, associated with auriferous pyrite, galenite, hematite, arsenopyrite, and magnetite ; gold at Country Harbor, Fort Clarence, Isaac's Harbor, Indian Harbor, Laidlow's Farm, Lawrencetown, Sherbrooke, Salmon River, Wine Cove, and other places.

HANTS Co.—Cheverie, oxide of manganese (in limestone) ; Petite

River, gypsum, oxide of manganese; Windsor, calcite, cryptomorphite (baronatrocalcite), howlite, glauber salt. The last three minerals are found in beds of gypsum.

Kings Co.—Black Rock, centrallassite, cerinite; cyanolite; a few miles east of Black Rock, prehnite? *stilbite!;* Cape Blomidon, on the coast between the cape and Cape Split, the following minerals occur in many places (some of the best localities are nearly opposite Cape Sharp): *analcite!! agate, amethyst! apophyllite!* calcite, chalcedony, chabazite, *gmelinite* (lederite), hematite, *heulandite!* laumontite, magnetite, malachite, *mesolite,* native copper (rare), *natrolite!* psilomelane, *stilbite!* thomsonite, faröelite, *quartz;* North Mountains, amethyst, bloodstone (rare), *ferruginous quartz, mesolite* (in soil); Long Point, five miles west of Black Rock, *heulandite, laumontite!! stilbite!!;* Morden, *apophyllite, mordenite;* Scott's Bay, *agate,* amethyst, *chalcedony,* mesolite, natrolite; Woodworth's Cove, a few miles west of Scott's Bay, *agate! chalcedony! jasper.*

Lunenberg Co.—Chester, Gold River, gold in quartz, pyrite, mispickel; Cape la Have, pyrite; The "Ovens," *gold,* pyrite, arsenopyrite; Petite River, gold in slate.

Pictou Co.—Pictou, *jet,* oxide of manganese, limonite; at Roder's Hill, six miles west of Pictou, barite; on Carribou River, gray copper and malachite in lignite; at Albion mines, coal, limonite; East River, limonite.

Queen's Co.—Westfield, gold in quartz, pyrite, arsenopyrite; Five Rivers, near Big Fall, gold in quartz, pyrite, arsenopyrite, limonite.

Richmond Co.—West of Plaister Cove, barite and calcite in sandstone; nearer the Cove, calcite, *fluorite* (blue), siderite.

Shelburne Co.—Shelburne, near mouth of harbor, garnets (in gneiss); near the town, rose quartz; at Jordan and Sable River, *staurolite* (abundant), schiller spar.

Sydney Co.—Hills east of Lochaber Lake, pyrite, chalcopyrite, siderite, hematite; Morristown, epidote in trap, gypsum.

Yarmouth Co.—Cream Pot, above Cranberry Hill, gold in quartz, pyrite; Cat Rock, Fouchu Point, asbestus, calcite.

NEWFOUNDLAND.

Antony's Island.—*Pyrite.*

Catalina Harbor.—On the shore, *pyrite!*

Chalky Hill.—*Feldspar.*

Copper Island, one of the Wadham group.—*Chalcopyrite.*

Conception Bay.—On the shore south of Brigus, bornite and gray copper in trap.

Bay of Islands.—Southern shore, *pyrite* in slate.

Lawn.—*Galenite, cerargyrite, proustite, argentite.*

Placentia Bay.—At La Manche, two miles eastward of Little Southern Harbor, *galenite!;* on the opposite side of the isthmus from Placentia Bay, barite in a large vein, occasionally accompanied by chalcopyrite.

Shoal Bay.—South of St. John's, chalcopyrite.

Trinity Bay.—Western extremity, barite.

Harbor Great St. Lawrence.—West side, fluorite, galenite.

BRITISH COLUMBIA.

Cariboo District.—Native gold, galena.

On Frazer River.—Gold, argentiferous tetrahedrite, cerargyrite, cinnabar.

Ominica District.—Native gold, argentiferous galenite, native silver, silver-amalgam.

Howe's Sound.—Bornite, molybdenite, mica.

Texada Id.—Magnetite.

II. BRIEF NOTICE OF FOREIGN MINING REGIONS.

The geographical positions of the different mining regions are learned with difficulty from the scattered notices in the course of a mineralogical treatise. A general review of the more important is therefore here given, to be used in connection with a good map.

A course across Europe, from southeast to northwest, passes over a large part of the mining regions, and it will be found most convenient to the memory to mention them in this order, commencing with the borders of Turkey.

1. The mines of the Bannat in Southern Hungary, near the borders of Turkey (about latitude 45°), situated principally at Orawitza, Saszka, Dognaszka, and Moldawa: argentiferous copper ores, chalcocite, malachite, copper pyrites, cuprite, galenite, ores of zinc, cobalt, native gold; yielding silver, gold, copper, and lead; *rock:* syenyte, and granular limestone.

2. The mines of Western Transylvania, about latitude 46°, situated between the rivers Maros and Aranyos, at Nagyag, Offenbanya, Salathna, and Vöröspatak: native gold, telluric gold, telluric silver, white tellurium, with galenite, blende, orpiment, realgar, stibnite, tetrahedrite, rhodochrosite or carbonate of manganese, manganblende; especially valuable in gold and silver.

3. In the mountain range, bounding Transylvania on the north, about latitude 47° 40′, at Nagybanya, Felsobanya, and Kapnik: native gold, red silver, argentiferous tetrahedrite, chalcopyrite or pyritous copper, blende, realgar, stibnite or gray antimony; *rock:* porphyry.

4. In the Königsberg Mountains, Northern Hungary, about latitude 48° 45′, at Schemnitz and Kremnitz: argentiferous galenite, and chalcopyrite, native gold, red silver ore, stibnite, some cobalt ores and bismuth, arsenopyrite or mispickel; particularly valuable for gold, silver and antimony; *rock:* diorite and porphyry.

5. To the east of the Königsberg Mountains, at Schmolnitz and Retzbanya: chalcopyrite, tetrahedrite, blende, stibnite; particularly valuable for copper; *rock:* clay slate.

6. Illyria, west of Hungary, at Bleiberg and Raibel (in Carinthia): argentiferous galenite, calamine, with some chalcopyrite and other ores, affording silver and zinc abundantly; *rock:* mountain limestone.—Also at Idria, native mercury and cinnabar, in argillaceous schist.

7. In Western Styria, at Schladming: arsenical nickel, copper nickel, native arsenic, arsenical iron, largely worked for nickel; *rock:* argillaceous slate. Illyria and Styria are noted also for their iron ores, especially siderite or spathic iron.

8. In the Tyrol, at Zell: argentiferous copper and iron ores, auriferous pyrite, native gold; *rock:* argillaceous slate.

9. In the Erzgebirge separating Bohemia from Saxony, and consisting principally of gneiss:

A. Bohemian or southern slope, at Joachimsthal, Mies, Schlackenwald, Zinnwald, Bleistadt, Przibram, Katherinenberg: tin ores, argentiferous galenite (worked principally for silver), arsenical cobalt ores, copper nickel; affording tin, silver, cobalt, nickel and arsenic.

B. Saxon or northern slope, at Altenberg, Geyer, Marienberg, Annaberg, Schneeberg, Ehrenfriedersdorf, Johanngeorgenstadt, Freiberg: argentiferous galenite (worked only for silver), tin ore, various cobalt and nickel ores, vitreous and pyritous copper; affording silver, tin, cobalt, nickel, bismuth, and copper.

10. In Silesia, in the Riesengebirge, an eastern extension of the Erzgebirge, at Kupferberg, Jauer, Reichenstein: ores of copper, cobalt, affording copper, cobalt, arsenic and sulphur.

11. In Silesia, in the low country east of the Riesengebirge, near the boundary of Poland, at Tarnowitz: calamine, smithsonite, blende, argentiferous galenite; affording zinc, silver and lead; *rock:* mountain limestone.

12. Northwest of Saxony, near latitude 51° 30′, at Eisleben, Gerlstadt. Sangerhausen, and Mansfeld: tetrahedrite, somewhat argentiferous, bornite or variegated copper ore, affording copper; *rock:* a marly bituminous schist (kupferschiefer) more recent than the Carboniferous strata.

13. In the Harzgebirge (Hartz Mountains), north of west from Eisleben, about latitude 51° 50′, at Clausthal, Zellerfeld, Lauthenthal, Wildemann, Grund, Andreasberg, Goslar, Lauterberg: chalcocite or vitreous copper, tetrahedrite, chalcopyrite, cobalt ores, copper nickel, ruby silver ore, argentiferous galenite, blende, antimony ores; affording silver, lead, copper, and some gold.

14. In Hesse-Cassel, to the southwest of the Hartz, at Riechelsdorf: arsenical cobalt, arsenical nickel, nickel ochre, native bismuth, bismuthinite, galenite, affording cobalt; *rock:* red sandstone. Also at Bieber, cobalt ores in mica slate.

15. In the Bavarian or Upper Rhine (Palatinate), near latitude 49° 45′, at Landsberg near Moschel, Wolfstein, and Morsfeld: cinnabar, native mercury, amalgam, horn quicksilver, pyrite, some tetrahedrite, and chalcopyrite; *rocks:* coal formation.

16. Province of the Lower Rhine, at Altenberg, near Aix la Chapelle (or Aachen): calamine, smithsonite, galenite, affording zinc; *rock:* limestone. The same just south in Netherlands, at Limburg, and also to the west at Vedrin, near Namur.

17. There are also copper mines at Saalfeld, west of Saxony, in Saxon-Meiningen, in Southern Westphalia near Siegen, in Nassau at Dillenberg, and elsewhere.

18. In Switzerland, at Canton du Valais: argentiferous galenite, and valuable nickel and cobalt ores.

19. The range of the Vosges parallel with the Rhine, about St.

Marie-aux-Mines: argentiferous galenite (affording 1-1000 of silver), with pyromorphites, tetrahedrite, antimonial sulphuret of silver, native silver, arsenical cobalt, native arsenic, and pyrite, occasionally auriferous; affording silver and lead; *rocks:* argillaceous schist, syenyte, and porphyry.

20. In France there are also the mining districts of the Alps, Auvergne or the Plateau of Central France, Brittany, and the Pyrenees, but none are very productive, except in iron ores. Brittany resembles Cornwall, and formerly yielded some tin and copper. The valley of Oisans in the Alps, at Allemont, contains argentiferous galenite, arsenical cobalt and nickel, gray copper, native mercury, and other ores, in talcose, micaceous and syenytic schists, but they are not now explored. The region of Central France is worked at this time only at Pont-Gibaud, in the department of Puy-de-Dome, and at Vialas and Villefort in the Gard. The former is a region of schistose and granite rocks, intersected by porphyry, affording some copper, antimony, lead, and silver; the latter of gneiss, affording lead and silver, from argentiferous galena. The French Pyrenees are worked at the present time only for iron.

21. In England there are two great metalliferous districts:

A. On the southwest, in Cornwall, and the adjoining county of Devonshire: pyritous copper and various other copper ores, tin ores, galenite, with some bismuth, cobalt, nickel and antimony ores; affording principally copper, tin, and lead; *rocks:* granite, gneiss, micaceous and argillaceous schist, elvanyte.

B. On the north, in Cumberland, the adjoining parts of Durham, with Yorkshire and Derbyshire, just south: galenite, and other lead ores, blende, copper ores, calamine and smithsonite (the zinc ores especially at Alstonmoor in Cumberland, and Castleton and Matlock, in Derbyshire), affording some zinc, and three-fifths of the lead of Great Britain, and some copper; *rock:* Carboniferous limestone.

C. There is also a vein of calamine, blende, and galenite, in the same limestone at Holywell, in Flintshire, on the north of Wales; another of calamine at Mendip Hills, in Southern England, south of the Bristol Channel, in Somersetshire, occurring in magnesian limestone; mines of copper on the Isle of Anglesey, in North Wales, in Westmoreland and the adjacent parts of Cumberland and Lancashire, in the southwest of Scotland, the Isle of Man, and at Ecton in Staffordshire, &c.

22. In Spain there are mines—

A. On the south, in the mountains near the Mediterranean coast, in New Grenada, and east to Carthagena, in Murcia; also in New Grenada, in the Sierra Nevada, or the mountains of Alpujarras, the Sierra Almagrera, the Sierra de Gador, just back of Almeria, and at Almazarron near Carthagena: galenite, which is argentiferous at the Sierra Almagrera and at Almazarron, affording full 1 per cent. of silver; *rock:* limestone, associated with schist and crystalline rocks.

B. The vicinity of the range of mountains running westward from Alcaraz (to the district of La Mancha), to Portugal. 1. On the south, near the centre of the province of Jaen, at Linares, latitude 38° 5′, longitude 3° 40′: galenite, cerussite, cuprite, malachite, in granite and schists; affording lead and copper. 2. In La Mancha, at Alcaraz, northeast of Linares, latitude 38° 45′: calamine affording abundantly zinc. 3. In the west extremity of La Mancha, near latitude 38° 38′, at Almaden: cinnabar, native mercury, pyrite, in clay slate. 4. Southwest of Almaden, in Southern Estremadura, and Northwestern Seville: tetrahedrite; at Guadalcanal, Cazalla, Rio Tinto: chalcanthite or copper vitriol, malachite, with some red silver ore, and native silver, in schists or limestones.

There are also mines of lead and copper at Falsete in Catalonia; in Galicia, a little tin ore; in the Asturias at Cabrales, copper ores.

23. In Sweden:—1. At Fahlun, in Dalecarlia: chalcopyrite, bornite; *rock*, syenyte and schists. At Finbo and Broddbo: tantalum ores, tin ore. At Sala: argentiferous galenite, affording lead and silver; *rock*, crystalline limestone. At Vena (or Wehna) and at Tunaberg: arsenical cobalt, erythrite; *rock*, mica slate and gneiss. At Dannemora and elsewhere: magnetic iron ore or magnetite.

24. In Norway, at Kongsberg: argentite or vitreous silver, native silver, horn silver, native gold, galenite, native arsenic, blende; *rock*, mica slate. At Modum and Skutterud: cobalt ores, native silver; *rock*, mica slate. At Arendal, magnetic iron ore.

25. In Russia:—In the Urals (mostly on the Asiatic side), at Ekatherinenberg, Beresof, Nischne Tagilsk, etc.: native gold, platinum, iridium, native copper, cuprite, malachite. 2. The Altai (Southern Siberia), at Kolyvan and Zmeof: native gold, native silver, argentiferous galena, cerussite, native copper, oxides of copper, malachite, chalcopyrite; *rocks*, metamorphic beds and porphyry. 3. In the Daouria Mountains, east of Lake Baikal, at Nertchinsk: argentiferous galenite, cerussite, mimetite, gray antimony, arsenopyrite, calamine, cinnabar; *rocks*, compact limestone and schists.

26. In Australia:—In Southern Queensland, and the northern part of New South Wales, or the New England district: tin ore or cassiterite abundant, with also native gold. In New South Wales, along the Blue Mountains and the continuation of the range parallel with the coast north and south, in the Bathurst, Mudgee, Lachlan and other districts: native gold, chalcopyrite, some cinnabar. In Victoria: native gold. In South Australia, especially at the Burra, Wallaroo, and Moonta mines: copper ores.

Other foreign mining regions are the copper mines of Cuba, and South America; the silver mines of Chili, Bolivia, Peru in South America, and of Mexico; the gold mines of South America, especially those of Brazil, South Africa, and of the Philippines, Borneo, New Guinea, New Caledonia, and New Zealand in Australasia; the quicksilver mines of Huanca Velica, Peru, and those of China; the tin mines of Malacca (principally on the island of Junk-Ceylon), and of the island of Banco between Borneo and Sumatra; of zinc, in China; of platinum, in Brazil, Colombia, St. Domingo, and Borneo; of palladium, in Brazil; of arsenic in Khoordistan, Turkey in Asia, and also in China; of nickel, in New Caledonia.

IV. DETERMINATION OF MINERALS.

In the determination of minerals, no one order in the succession in which characters should be examined answers for all minerals, or even for all of the same section of species.

A. For species having a metallic lustre :

Color will be first noted ; and then *streak*—that is, the *color* of the mineral on a surface scratched or abraded by a fine file, or when *very* finely powdered, and the *lustre* of the powder or abraded surface, whether metallic like the mineral or unmetallic. *Hardness* should be ascertained when obtaining the streak.

Blowpipe and *chemical characters* are of the highest value, giving generally the most certain results.

Specific gravity is especially distinctive with species having a metallic lustre, since the differences in density among such species are usually large.*

Crystalline form and *cleavage* are of first importance, whenever the specimen allows of their determination.

B. For species without metallic lustre :

Streak is sometimes of importance, especially among species in which it is highly colored.

Color is generally of little value owing to the variations that frequently come in through impurities.

Lustre is one of the first characters the eye will observe, but its variation under most species is wide, and often it is of little value. *State of aggregation* and *fracture* for the most part serve to distinguish only varieties.

Hardness is also often a varying character, the range under some species being from 1 to 6 in the scale of hardness ; and still its indications are generally important.

Crystalline form and *cleavage* are always important when observable..

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* In using the spiral balance of Jolly (page 65), the spiral spring is put at any desired height by means of the sliding rod C. The stand B is raised so that the lower pan, *d*, shall be in the water, while the other, *c*, is above it. The position of the index, or signal, *m*, is then noted, by sighting across it and observing that the index and the image of it in the mirror are in the same horizontal line ; let *s* stand for it. Next put the fragment of the mineral in *c*, and drop the stand B until the lower pan hangs free in the water, and note the position of *m*, which we may represent by *t* ; $t-s$ will equal the weight in the air. Now place the fragment in the lower pan. and after adjusting again the stand B, the position of *m* is noted as before ; call it *u*. Then $t-u$ = loss of weight in water. From these values the specific gravity is at once obtained.

Taste is of limited value, as few minerals are sufficiently soluble; but among soluble minerals it is easily observed, and often decisive.

Action of acids, cold or hot, in trials as to effervescence, solubility, gelatinizing or not, and in making solutions for examination with other reagents, is a very important means of distinguishing species.

Blowpipe reactions are easily obtained, and of the highest value.

Specific gravity is an important reliance.

Refraction and *polarization* afford valuable criteria for distinguishing species, and in a few cases no other means are so reliable short of chemical analysis.

The following hints may be of service to the beginner in the science, by enabling him to overcome a difficulty in the outset, arising from the various forms and appearance of the minerals quartz and limestone. Quartz occurs of nearly every color, and of various degrees of glassy lustre to a dull stone without the slightest glistening. The common grayish cobble-stones of the fields are usually quartz, and others are dull red and brown; from these there are gradual transitions to the pellucid quartz crystal that looks like the best of glass. Sandstones and freestones are often wholly quartz, and the seashore sands are mostly of the same material. It is therefore probable that this mineral will be often encountered in mineralogical rambles. Let the first trial of specimens obtained be made with a file, or the point of a knife, or some other means of trying the hardness; if the file makes no impression, there is reason to suspect the mineral to be quartz; and if on breaking it, no regular structure or cleavage plane is observed, but it breaks in all directions with a similar surface and a more or less vitreous lustre, the probability is much strengthened that this conclusion is correct. The blowpipe may next be used; and if there is no fusion produced by it in a careful trial there can be little doubt that the specimen is in fact quartz.

Calcite (calcium carbonate), including limestone, is another very common species. If the mineral collected is rather easily impressible with a file, it may be of this species; if it effervesces freely when placed in a test-tube containing dilute hydrochloric acid, and is finally dissolved, the probability of its being carbonate of lime is increased; if the blowpipe produces no trace of fusion, but a brilliant light from the fragment before it, but little doubt remains on this point. Crystalline fragments of calcite break with three equal oblique cleavages.

Familiarized with these two Protean minerals by the trials here alluded to, the student has already surmounted the principal difficulties in the way of future progress. Frequently the young beginner, who has devoted some time to collecting all the different colored stones in his neighborhood, on presenting them for names to some practised mineralogist, is a little disappointed to learn that, with two or three exceptions, his large variety includes nothing but limestone and quartz. He is perhaps gratified, however, at being told that he may call this specimen yellow jasper, that red jasper, another flint, and another hornstone, others chert, granular quartz, ferruginous quartz, chalcedony, prase, smoky quartz, greasy quartz, milky quartz, agate, plasma, hyaline quartz, quartz crystal, basanite, radiated quartz, tabular quartz, etc., etc.; and it is often the case, in this state of his knowledge, that he is best pleased with some treatise on the science in which all these various stones are treated with as much prominence as if actually distinct species; being loth to receive the unwelcome truth, that his whole extensive cabinet contains only one mineral. But the mineralogical student has already made good progress when this truth is freely admitted, and quartz and limestone, in all their varieties, have become known to him.

The student should be familiar with the use of the blowpipe and the reactions, as explained on pages 82 and 85; and it would be still better if a fuller treatise on the subject had been carefully studied. He should be supplied with the three acids in glass-stoppered bottles; a fourth bottle containing hydrochloric acid diluted one-half with water, for obtaining effervescence with carbonates; test tubes; and also the ordinary blowpipe apparatus and tests, including platinum wire, platinum forceps, glass tube, "cobalt solution," litmus and turmeric paper, etc.

Also the following:

A *small file*, three-cornered or flat, for testing hardness.

A *knife* with a pointed blade of good steel, for trying hardness. It may be magnetized, to be used as a magnet, though a good horseshoe *magnet* of small size is better.

The series of crystallized minerals, constituting the *scale of hardness* (see page 63). Diamond and talc are least essential.

Cutting pliers, for removing chips of a mineral for blowpipe or chemical assay.

A *pocket-lens*.

A *hammer* weighing about two pounds, resembling a stone-cutter's hammer, having a flat face, and at the opposite end an edge having the same direction as the handle. The handle should be made of the best hickory, and the mortise to receive it should be as large as the handle. A foot scale should be marked on the handle of the hammer, divided into inches, the smallest divisions needed. It will be often of use in getting out a yard-stick, or a ten-foot pole, for large measurements. A similar hammer, having the upper part prolonged to a blunt point, to be used like a pick, is often convenient.

A hammer of half a pound weight, like the figure, to be used in trimming specimens.

A small jeweler's hammer, for trying the malleability of globules obtained by the blowpipe, and for other purposes, and a small piece of steel for an anvil.

Two steel chisels, one six inches long, and the other three. When it is desired to pry open seams in rocks with the larger chisel, two pieces of steel plate should be provided to place on opposite sides of the chisel, after an opening is obtained; this protects the chisel and diminishes friction while driving it.

For blasting, if this is desired:

Three hand-drills 18, 24, and 36 inches long, an inch in diameter. The best form is a square bar of steel, with a diagonal edge at one end. The three are designed to follow one another.

A sledge-hammer of six or eight pounds weight, to use in driving the drill.

A sledge-hammer of ten or twelve pounds weight, for breaking up the blasted rock.

A round iron spoon, at the end of a wire fifteen or eighteen inches long, for removing the pulverized rock from the drill-hole.

A crowbar, a pickaxe, and a hoe, for removing stones and earth before or after blasting.

Cartridges of blasting powder, to use in wet holes. They should one-third fill the drill-hole. After the charge is put in, the hole should be filled with sand and gravel alone without ramming. If any ramming material is used, plaster of Paris is the best, which has been wet and afterwards scraped to a powder.

Patent fuse for slow match, to be inserted in the cartridge, and to lead out of the drill-hole.

The table beyond is prepared especially to aid in instruction, and comprises, with few exceptions, only the species that are described in large type through the work, exclusive of the hydrocarbon compounds. The following abbreviations are used in it, in addition to those explained on page 90. With reference to colors: *bnh*, brownish; *bkh*, blackish; *gnh*, greenish; *gyh*, grayish; *rdh*, reddish. The acids: *nit.*, nitric acid; *sulph. acid*, sulphuric acid; *HCl.*, hydrocloric acid; *sulph.*, sulphurous or sulphurous acid.

Reactions: *gelatinizing with acid*, see page 81; *reaction for sulphur with soda*, see page 89; *blue* or *red color with cobalt solution*, see page 88; *hydrous*, yielding water in a closed tube; *anhydrous*, not yielding water in a closed tube, or only traces, see page 86; B.B. *lithium-red color*, see page 87; B.B. *green flame due to boron*, see page 87; *coal* is used for charcoal; *fus.* for fusible; *infus.* for infusible; *sol.* for soluble; *st.* for streak.

In using the blowpipe it is important to remember that a trial of fusibility with the forceps, if not at once producing fusion, should be made on a piece of the mineral not larger than the fourth of an ordinary pin-head, and it should be either oblong and slender, or thin, and be made to project considerably beyond the points of the forceps, lest the forceps carry off the heat, and cause a failure where there ought to be success. Further, it should be in mind, that in using charcoal, a white coating is always a consequence of burning it, since the ash from its own combustion is white. Again, before testing for sulphur by means of soda and a polished surface of silver, it is necessary to try the flame and the soda for sulphur. Gas-flame always contains traces of sulphur, and sometimes too much for safe conclusions in this trial.

A mineralogist sometimes has occasion to measure distances, and by the following method he may make himself quite an accurate odometer:

Let him first find, or make, along a roadside, a measured distance of 800 to 1,000 feet, and then walk it at his ordinary walking pace three or four times, and note the number of steps. He will thus ascertain the actual length of his pace, and also find that in his ordinary walk it does not differ much from thirty inches; it may be an inch or two less, or one, two, or three more than this. Now four times thirty inches is ten feet. If then, as he walks, he counts one for every *fourth step*, each unit in the count will stand for ten feet nearly, and 100, for 1,000 feet nearly. If his pace is thirty-one inches, let him add a unit for every thirty in the counting, or, which is the same thing, call his thirty thirty-one, and the needed correction will be made; or if his step is twenty-nine and one-half inches, subtract one from every sixty in the counting, or in other words duplicate the sixty. Or the correction may be made at the end of the pacing; if at 600, this number, after adding a thirtieth, becomes 620; and the distance would hence be 6,200 feet. With a little practice the counting may be carried on almost unconsciously, and when the thoughts are elsewhere; that is, unless there is a talking friend by one's side.

An instrument, called a *pedometer*, of the shape and size of a small watch, is to be had of instrument makers, which, if carried in the waistcoat pocket, will do the registering for the pedestrian and note the distance, without any attention on his part. But the odometer explained above, when once in working order, is always at hand.

SYNOPSIS OF THE ARRANGEMENT.

I. ELEMENTS.

1. **Lustre metallic; liquid.**
2. **Lustre metallic; malleable and eminently sectile.**
3. **Lustre metallic; brittle; B.B. on coal, wholly volatile, with no sulphurous fumes.**
4. **Lustre metallic; brittle; H.=1-2; leaves a trace on paper; B.B. on coal, infusible, no fumes or odor.**
5. **Unmetallic; burns readily with a blue flame.**
6. **Lustre adamantine; H.=10.**

II. MINERALS NOT ELEMENTS, THAT B.B. ON COAL ARE WHOLLY VOLATILE.

1. **Lustre metallic ; streak metallic.**
2. **Lustre unmetallic ; streak same as color.**

III. COMPOUNDS, OF GOLD, SILVER, COPPER, LEAD, TIN, MERCURY, CHROMIUM, COBALT, MANGANESE : yielding, on heating, a malleable, or liquid (for mercury ores), metallic globule, as explained on pages 389–393, or else affording a decisive blowpipe reaction, proving the presence of one or more of these metals.

A. Yielding a malleable globule B.B. on coal with, if not without, soda.

1. **Compounds of Gold.**
2. **Compounds of Silver.**
3. **Compounds of Copper.**
4. **Compounds of Lead.**
5. **Compounds of Tin.**

B. Yielding drops of mercury with soda in a closed tube.

1. **Compounds of Mercury.**

C. A decisive reaction with borax or salt of phosphorus for chromium, cobalt, or manganese.

1. **Compounds of Chromium.**
2. **Compounds of Cobalt.**
3. **Compounds of Manganese.**

IV. MINERALS OF METALLIC OR SUBMETALLIC LUSTRE, NOT INCLUDED IN PRECEDING DIVISIONS.

1. Yielding fumes in the open tube or on coal, but not wholly vaporizable.

A. Streak metallic.
B. Streak unmetallic.
  a. Fumes sulphurous only.
  b. Fumes arsenical, with or without sulphurous.

2. Not yielding fumes of any kind; streak unmetallic.

A. B.B. easily fusible, giving a magnetic bead; lustre sub metallic.
B. Infusible, or nearly so.
  a. Reaction for iron; anhydrous.
  b. Reaction for iron; hydrous.
  c. Reaction for chromium or titanium.
  d. Reaction for osmium with nitre.

V. MINERALS OF UNMETALLIC LUSTRE.

1. Having an acid, alkaline, alum-like, or styptic taste.

A. CARBONATES: Taste alkaline; effervescing with HCl.
B. SULPHATES: No effervescence; reaction for sulphur with soda.
C. NITRATES: With sulph. acid, reddish acrid fumes; no action with HCl; deflagrate.
D. CHLORIDES: With sulph. acid, acrid fumes of HCl; no fumes with HCl.
E. BORATES: No effervescence; reaction for boron when moistened with sulph. acid.

2. Not having either of the above-mentioned kinds of taste.

A. CARBONATES: Effervescing with HCl.
  a. Infusible; assay alkaline after ignition.
  b. Infusible; become magnetic and not alkaline, on ignition.
  c. Infusible; B.B. on coal with soda, zinc oxide vapors.
  d. Infusible; B.B. on coal reaction for nickel.
  e. Fusible; assay alkaline after ignition.

B. SULPHATES: Reaction for sulphur with soda.
  a. Fusible; assay alkaline after fusion.
  b. Fusible; reaction for iron.
  c. Infusible.

C. ARSENATES: on coal arsenical fumes.

D. SILICATES, PHOSPHATES, OXIDES:

Species not included in the preceding subdivisions.

I. STREAK DEEP RED, YELLOW, BROWNISH-YELLOW, GREEN, OR BLACK.

A. Infusible, or fusible with difficulty.
B. Fusible without much difficulty.

II. STREAK GRAYISH OR NOT COLORED.

1. Infusible.

- A. Gelatinize with acid, forming a stiff jelly.
- B. Not forming a stiff jelly; hydrous.
  - *a.* Blue color with cobalt solution.
  - *b.* Reddish or pink color with cobalt solution.
  - *c.* Not blue or red with cobalt solution.
- C. Not forming a stiff jelly; anhydrous.
  - *a.* Blue color with cobalt solution.
  - *b.* Not blue or reddish color with cobalt solution.

2. Fusible with more or less difficulty.

- A. Gelatinize and form a stiff jelly.
  - *a.* Hydrous; fuse easily.
  - *b.* Hydrous; fuse with much difficulty.
  - *c.* Anhydrous.
    - *α.* No reaction for sulphur; no coating on coal.
    - *β.* Reaction for sulphur with soda.
- B. Not gelatinizing.
  - 1. Structure eminently micaceous; folia tough, pearly, and H. of surface of folia not over 3·5; anhydrous or hydrous.
  - 2. Structure not eminently micaceous.
    - *a.* Hydrous.
      - *α.* No reaction for phosphorus, or boron.
        - †. H.=1 to 3; lustre not at all vitreous.
        - ††. H.=3·5-6·5; lustre of cleavage surface sometimes pearly; elsewhere vitreous.
      - *β.* Reaction for phosphorus or boron.
    - *b.* Anhydrous.
      - *α.* B.B. lithium-red flame.
      - *β.* B.B. boron reaction (green flame).
      - *γ.* B.B. reaction for titanium.
      - *δ.* B.B. reaction for fluorine or phosphorus.
      - *ε.* B.B. reaction for iron.
      - *ϑ.* B.B. no reaction for iron: not of the preceding subdivisions.

I. ELEMENTS.

1. Lustre metallic; liquid.

MERCURY, p. 128. This is the only metallic mineral which is liquid at the ordinary temperature and atmospheric pressure.

2. Lustre metallic; malleable and eminently sectile.

GOLD, p. 109. G.=15–19·5; yellow; fusible; not sol. in nitric acid or HCl, but sol. in aqua regia.
PLATINUM, p. 124. G.=16–19; nearly white; infusible; insol. in nitric acid.
PALLADIUM, p. 127. G.=11·3–11·8; grayish-white; diff. fusible; sol. in nitric acid.
SILVER, p. 116. G.=10–11·1; white; fusible; sol. in nitric acid, and deposited again on copper.
COPPER, p. 131. G.=8·84; copper-red; fus.; sol. in nitric acid, and the solution becomes sky-blue when ammonia is added
IRON, p. 171. G.=7·3–7·8; iron-gray; attracted by the magnet.

The only other mineral of metallic lustre that is also malleable and eminently sectile is *argentite*, a silver sulphide, along with two others of like composition but different crystallization.

3. Lustre metallic; brittle; B.B. wholly volatile, but give off no sulphurous fumes.

BISMUTH, p. 101. G.=9·73; reddish-white; on coal a yellow coating; fumes inod.
ANTIMONY, p. 100. G.=6·6–6·7; tin-white; fumes dense wh., inod.
ARSENIC, p. 98. G.=5·9–6; tin-white; fumes white, alliaceous.
TELLURIUM, p. 96. G.=6·1–6·3; tin-white; fus.; fumes white; flame green.

The only other mineral that is wholly volatile, and also gives off no sulphurous fumes, is allemontite, an antimony arsenide.

4. Lustre metallic; H.=1–2; B.B. on coal infusible; no fumes.

GRAPHITE, p. 107.

5. Lustre unmetallic; takes fire readily in the flame of a candle, and burns with a blue flame.

SULPHUR, p. 94.

6. Lustre adamantine; H.=10.

DIAMOND, p. 103. Easily scratches corundum or sapphire.

II. MINERALS, NOT ELEMENTS, THAT ARE WHOLLY VOLATILE B.B. ON COAL.

1. Lustre metallic ; streak metallic.

TETRADYMITE, p. 102. G.=7·2–7·9 ; pale steel-gray ; so soft as to soil paper ; on coal white fumes ; flame bluish-green; sometimes sulph. odor ; in open tube, a coating which fuses to white drops.
BISMUTHINITE, p. 102. G.=6·4–7·2; whitish lead-gray; on coal yellow coating and sulph. odor.
STIBNITE, p. 100. G.=4·5-4·52 ; lead-gray ; on coal dense wh. fumes and wh. coating.

2. Lustre unmetallic ; streak same nearly as color.

ORPIMENT, p. 99. Lemon yellow ; on coal burns, odor alliaceous.
REALGAR, p. 99. Bright red ; on coal burns, odor alliaceous.
ARSENOLITE, p. 99. White ; on coal, odor alliaceous.
VALENTINITE, p. 101. White ; on coal dense wh. fumes, inco.
CINNABAR, p. 128. Red ; in open tube, sulph. odor, coating of mercury globules.
SALMIAK, p. 230. White ; saline and pungent taste ; on coal, fumes of ammonia.

III. COMPOUNDS OF GOLD, SILVER, MERCURY, COPPER, LEAD, TIN, CHROMIUM, COBALT, MANGANESE.

A. Yielding a malleable globule B.B. on coal, with or without soda.

1. COMPOUNDS OF GOLD.

Yield gold, or an alloy of gold and silver, B.B. on coal. The TELLURIUM ORES, pp. 115, 116, give a coating of drops of tellurous acid in open tube.

2. COMPOUNDS OF SILVER.

B.B. easily fusible ; G. above 5 ; yield, with few exceptions, a globule of silver (white and malleable), on coal, with soda, if not without ; and, in the exceptions, silver globule obtained by cupellation. All have metallic lustre excepting cerargyrite, bromyrite, and iodyrite.

a. EMINENTLY SECTILE.

ARGENTITE, p. 117. G.=7·2–7·4; lustre metallic; on coal sulph. fumes.

CERARGYRITE, p. 120. G.=5·3–5·6; lustre like that of white, gray, or greenish to brownish wax.

b. NOT SECTILE; ON COAL ODOROUS FUMES.

SULPHIDES, p. 118. Gives sulph. odor.

ARSENICAL ORES, pp. 119, 120. Alliaceous fumes.

SELENIDES, p. 118. Horse-radish odor.

c. NOT SECTILE; ON COAL FUMES OF ANTIMONY OR TELLURIUM.

ANTIMONIAL ORES, pp. 119, 120. Dense white fumes of antimony; with also, if sulphur is present, sulph. fumes.

TELLURIDES, p. 118. In open tube coating which fuses to drops of tellurous acid.

STROMEYERITE, p. 119. Contains copper, and requires cupellation in order to obtain a globule of silver.

3. COMPOUNDS OF COPPER.

Unless iron is present, a globule of metallic copper is obtained with soda, if not without, on coal; with a nitric acid solution and ammonia in excess a bright blue color; moistened with HCl the blue flame of chloride of copper; and a clean surface of iron in the nitric solution becomes coated with copper.

1. METALLIC LUSTRE.

SULPHIDES, pp. 132–136. On coal or in open tube sulph. fumes.

ARSENIDES, SELENIDES, p. 135.

ANTIMONIAL SULPHIDES, p. 135, 136.

2. LUSTRE UNMETALLIC; B.B. NEITHER ON COAL NOR IN OPEN TUBE ANY ODOROUS FUMES; NO TASTE.

CUPRITE, p. 136. H.=3·5–4; G.=5·8–6·2; isometric; deep red, streak bnh-red.

ATACAMITE, p. 136. Darkish bright green, streak gnh; B.B. on coal fuses, coloring O.F. azure-blue, with a green edge; easily sol. in acids.

PHOSPHATES, p. 139.

MALACHITE, p. 140. H.=3–4; G.=3·7–4; light to deep green; effervesces with HCl.

AZURITE, p. 141. H.=3·5–4·5; G.=3·5–3·9; deep blue; effervesces with HCl.

DIOPTASE, p. 141. H.=5; G.=3·25–3·35; emerald-green; B.B. infusible.

CHRYSOCOLLA, p. 142. Bluish-green; B.B. infusible.

3. LUSTRE UNMETALLIC; B.B. ON COAL, OR IN CLOSED TUBE, ODOROUS FUMES OF ARSENIC OR SULPHUR, OR REACTION FOR SULPHUR.

ARSENATES, p. 139. On coal arsenical fumes.
CHALCANTHITE, p. 137. Blue; taste nauseous; astringent.
Also *Stromeyerite*, *Stannite*, *Bournonite* give reactions for copper.

4. COMPOUNDS OF LEAD.

Yield B.B. on coal a dark lemon-yellow coating; finally, with soda, if not without, a globule (metallic and malleable) of lead is obtained; but by continued blowing with O.F. the lead all goes off in fumes, leaving other more stable metals (silver, etc.) behind. Sulphurous, selenious and tellurous fumes easily obtained either on coal or in an open tube from the sulphide, selenide, tellurides; and arsenical or antimonial fumes from ores containing arsenic or antimony. None have taste.

1. LUSTRE METALLIC.

GALENITE, p. 145. H.=2·5; G.=7·2–7·7; cleavage cubic eminent; lead-gray, streak same; in open tube sulph.
SELENIDES, TELLURIDES, ANTIMONIAL and **ARSENICAL SULPHIDES**, page 149.

2. LUSTRE UNMETALLIC; NO ODOROUS FUMES, OR REACTION FOR SULPHUR.

MINIUM, p. 149. Bright red, streak same.
CROCOITE, p. 150. Monoclinic; bright red, streak orange-yellow; B.B. with salt of phosphorus emerald-green bead.
PYROMORPHITE, p. 151. Hexagonal; bright green to brown, rarely orange-yellow; streak white. B.B. fuses easily, coloring flame bluish-green.
CERUSSITE, p. 152. Trimetric, often in twins; H.=3–3·5; G.=6·4–6·8; white, gyh; lustre adamantine; often tarnished to grayish metallic adamantine. Effervesces in dilute nitric acid.

3. UNMETALLIC; REACTION FOR SULPHUR.

ANGLESITE, page 150. Trimetric; white, gyh; fuses in flame of candle; B.B. reaction for sulphur; no effervescence with acids.

5. COMPOUNDS OF TIN.

CASSITERITE, p. 160. H.=6–7; G.=6·4–7·1; brown, gyh, ywh, black; B.B. infusible; on coal with soda a globule of tin, yield no fumes.

Stannite, p. 158. A copper, iron, and tin sulphide, does not give B.B. a metallic malleable globule.

B. Yield drops of mercury in closed tube with or without soda.

COMPOUNDS OF MERCURY.

CINNABAR, p. 128. H.=2–2·5 ; G.=8–9 ; bright red, bnh red, gyh ; streak scarlet.

AMALGAM, p. 117. H.=3–3·5 ; G.=13–14 ; silver-white ; yields silver B.B. on coal.

Spaniolite, p. 136, a variety of tetrahedrite, yields mercury.

C. No malleable globule ; decisive reaction with borax or salt of phosphorus for chromium, cobalt, or manganese.

1. COMPOUNDS OF CHROMIUM.

Give with borax an emerald-green bead in both flames.

CHROMITE, p. 180. H.=5·5 ; G.=4·3–4·5 ; isometric, often in octahedrons, massive ; submetallic ; bnh iron-black, streak brown ; B.B. on coal becomes magnetic ; with borax, a bead which is emerald-green on cooling.

CROCOITE, p. 150. H.=2·5–3 ; G.=5·9–6·1 ; bright red, streak orange ; B.B. fuses very easily, on coal globule of lead, and with salt of phosphorus emerald-green bead. *Phœnicochroite* and *Vauquelinite* are other lead chromates.

2. COMPOUNDS OF COBALT.

Give a blue color with borax after, if not before, roasting.

[When much nickel or iron is present the blue color is not obtained ; and species or varieties of this kind are not here included.]

1. LUSTRE METALLIC.

COBALTITE, p. 165. H.=5·5 ; G.=6–6·3 ; isometric and pyritohedral ; rdh silver-white, streak grayish-black ; B.B. on coal sulph. and arsen. fumes, and a magnetic globule.

SMALTITE, p. 165. H.=5·5–6 ; G.=6·4–7·2 ; tin-white, streak gyh black ; B.B. on coal alliaceous fumes ; most varieties fail to give the blue color immediately with borax, because of the iron and nickel present.

LINNÆITE, p. 164. H.=5·5 ; G.=4·8–5 ; isometric ; pale steel-gray, copper-red tarnish, streak bkh gray. B.B. on coal sulph. fumes.

2. LUSTRE UNMETALLIC.

ERYTHRITE, p. 167. H.=1·5–2·5 ; G.=2·95 ; monoclinic, one highly perfect cleavage, also earthy ; rose-red, peach-blossom red, streak reddish ; B.B. fuses easily ; yields water.

BIEBERITE, p. 168. A cobalt sulphate.
REMINGTONITE, p. 168. A hydrous cobalt carbonate.

3. COMPOUNDS OF MANGANESE.

Give an amethystine globule in O.F. with borax. [The globule looks black if too much of the manganese mineral is used, and with a large excess may be opaque.]

1. GIVES OFF CARBONIC ACID WHEN TREATED WITH DILUTE H Cl; LUSTRE UNMETALLIC.

RHODOCHROSITE, p. 191. H.=3·5–4·5; G.=3·4–3·7; rose-red.

Also manganese-bearing varieties of calcite, dolomite, ankerite, siderite, all of which have the cleavage and general form of rhodochrosite; when containing a few per cent. of manganese they often turn black on exposure.

2. TREATED WITH H Cl YIELDS CHLORINE FUMES.

MANGANITE, p. 189. H.=4; G.=4·2–4·4; in oblong trimetric prisms; grayish-black, streak reddish-brown; lustre submetallic; B.B. infusible; yields water.
PSILOMELANE, p. 189. H.=5–7; G.=3·7–4·7; amorphous; black, streak brownish-black; submetallic; B.B. infusible; yields water.
Wad is similar, but often contains cobalt.
PYROLUSITE, p. 188. H.=2–2·5; G.=4·82; in stoutish trimetric crystals; metallic; dark steel-gray, streak black or bluish-black; B.B. infusible; yields no water.
BRAUNITE and **HAUSMANNITE** (p. 189) are other anhydrous manganese oxides.
FRANKLINITE, p. 179. H.=5·5–6·5; G.=5–5·1; in octahedrons and massive; iron-black, streak dark reddish brown; B.B. infusible; but little chlorine with H Cl.

3. CO_2 OR Cl NOT GIVEN OFF WHEN TREATED WITH H Cl; ANHYDROUS.

RHODONITE, p. 247. H.=5·5–6·5; G.=3·4–3·68; rose-red; B.B. fuses easily.
TRIPLITE, p. 191. H.=5·5; G.=3·4–3·8; brown to black; B,B. fuses very easily, globule magnetic; sol. in H Cl.
HELVITE, p. 256. H.=6–6·5; G.=3·1–3·3; in yellowish tetrahedrons; B.B. fuses easily.
SPESSARTITE (Manganesian Garnet), p. 258. H.=6·5–7; G.=3·7–4·4; in dodecahedrons and trapezohedrons; red, brownish-red; B.B. fuses easily.
TEPHROITE, p. 256. H.=5·5–6; G.=4–4·12; reddish to brown and gray; B.B. fuses not very easily; gelat. in H Cl.
Knebelite, p. 256, is related, and also gelatinizes.

HAUERITE, p. 188. H.=4; G.=3·46; isometric; reddish brown, streak brownish-red. B.B. yields sulphur, after roasting reaction for manganese.
ALABANDITE, p. 188. H.=3·5–4; G.=4; submetallic, iron-black; streak green; B.B. on coal sulphur, after roasting reaction for manganese.

Vesuvianite, epidote, axinite, ilvaite, göthite, include varieties that give reaction for manganese.

IV. MINERALS OF METALLIC OR SUB-METALLIC LUSTRE NOT INCLUDED IN PRECEDING DIVISIONS.

1. YIELDING FUMES IN THE OPEN TUBE OR ON COAL, BUT NOT WHOLLY VAPORIZABLE.

A. STREAK METALLIC.

MOLYBDENITE, p. 96. H.=1–1·5; G.=4·4–4·8; lead-gray, and leaves trace on paper; B.B. on coal sulphurous fumes
BISMUTHINITE, p. 102. H.=2; G.=6·4–7·2; lead-gray, whitish; B.B. on coal sulphurous fumes, and yellow bismuth oxide; sol. in hot nitric acid and a white precip. on diluting with water

B. STREAK UNMETALLIC.

a. FUMES SULPHUROUS ONLY.

PYRITE, p. 172. H.=6–6·5; G.=4·8–5·2: isometric and pyritohedral; pale brass-yellow, streak gnh black, bnh black; B.B. on coal, fuses to a magnetic globule.
MARCASITE, p. 174. H.=6–6·5; G.=4·68–4·85; *trimetric;* pale bronze-yellow; streak gyh black, bnh black; B.B. like pyrite.
PYRRHOTITE, p. 174. H.=3·5–4·5; G.=4·4–4·68; hexagonal; bronze-yellow, rdh; streak gyh black; slightly magnetic; B.B. fuses to a magnetic mass.
MILLERITE, p. 164. H.=3–3·5; G.=4·6–5·7, rhombohedral, usually in acicular or capillary forms, also in fibrous crusts; brass-yellow, somewhat bronze-like; B.B. fuses to a globule, reacts for nickel.
LINNÆITE, p. 164. H.=5·5: G.=4·8–5; isometric; pale steel-gray, copper-red tarnish; streak blackish-gray; B.B. on coal fuses

to a magnetic globule, after roasting gives reactions for nickel, cobalt, and iron.

SPHALERITE, p. 154. H.=3·5–4; G.=3·9–4·2; isometric; lustre submetallic; streak nearly uncolored; nearly infusible alone and with borax; on coal a coating of zinc oxide.

b. ARSENICAL FUMES, WITH OR WITHOUT SULPHUROUS.

ARSENOPYRITE, p. 175. H.=5–6; G.=6–6·4; trimetric; white, gyh, streak dark gyh black. In closed tube, red arsenic sulphide and metallic arsenic; B.B. on coal fuses to magnetic globule.

GERSDORFFITE, p. 166. H.=5·5; G.=5·6–6·9; isometric, pyritohedral; white, gyh, streak grayish-black. In closed tube arsenic sulphide, on coal not magnetic, and reacts for nickel and often cobalt.

NICCOLITE, p. 166. H.=5–5·5; G.=7·3–7·7; hexagonal; pale copper-red, streak pale bnh black; in open tube, coating of arsenous acid; B.B. on coal no sulph. fumes, fuses to globule which reacts for iron, cobalt and nickel.

SMALTITE, p. 165. H.=5·5–6; G.=6·4–7·2; isometric; tin-white; streak gyh black; on coal, no fumes of sulphur or only in traces.

2. NOT YIELDING FUMES OF ANY KIND. STREAK UNMETALLIC.

A. B.B. EASILY FUSIBLE, AND GIVING A MAGNETIC BEAD. LUSTRE SUBMETALLIC.

ILVAITE, p. 263. H.=5·5–6; G.=3·7–4·2; trimetric; gyh iron-black, streak gnh or bnh black; gelat. with H Cl.

ALLANITE, p. 263. H.=5·5–6; G.=3–4·2; monoclinic; bnh pitch-black, streak gyh, bnh; B.B. fuses easily; most varieties gelat. with HCl.

WOLFRAMITE, p. 183. H.=5–5·5; G.=7·1–7·6; monoclinic; gyh black or bnh black; B.B. fuses easily, and reacts for iron, manganese, and tungsten.

B. INFUSIBLE OR NEARLY SO.

a. REACTION FOR IRON; ANHYDROUS; H.=5–6·5.

MAGNETITE, p. 178. G.=4·9–5·2; isometric; iron-black; streak black; strongly magnetic.

MENACCANITE, p. 178. G.=4·5–5; rhombohedral; iron-black: streak submetallic, black to bnh red; very slightly magnetic.

HEMATITE, p. 176. G.=4·5–5·3; rhombohedral; gyh iron-black, in very thin splinters or scales blood-red by transmitted light; streak red; sometimes slightly magnetic.

MARTITE, p. 177. Same as hematite, but isometric.

TANTALITE, p. 184. G.=7–8; trimetric; iron-black, streak rdh brown to black.

FRANKLINITE, p. 179. H.=5·5–6·5; G.=4·8–5·1; octahedral, massive; iron-black; streak dark rdh brown; slightly attracted by magnet; with soda reaction for manganese.

COLUMBITE, p. 183. G.=5·4–6·5; trimetric; iron-black, gyh black, streak dark red to black, often with a bluish steel-tarnish.

SAMARSKITE, p. 202. H.=5·5–7; G.=5·6–5·8; velvet-black, pitch-black; streak dark rdh brown; B.B. glows; fuses with difficulty.

b. REACTION FOR IRON; HYDROUS; LUSTRE SUBMETALLIC.

LIMONITE, p. 181. G.=3·6–4; massive, often stalactitic and tuberose with surface sometimes highly lustrous, often subfibrous in structure; black, bnh black; streak bnh yellow.

GOTHITE, p. 182. G.=4·0–4·4; trimetric; also fibrous and massive; bkh brown; streak bnh yellow.

TURGITE, p. 182. G.=3·6–4·68; fibrous and massive, looking like limonite; black, rdh black, streak red; in closed tube decrepitates, which is not the case with gōthite and limonite.

c. REACTION FOR CHROMIUM OR TITANIUM.

CHROMITE, p. 180. H.=5–5; G.=4·3–4·6; isometric; submetallic; bnh iron-black, streak brown; B.B. with borax gives a bead which on cooling is chrome-green.

RUTILE, p. 162. H.=6–6·5; G.=4·18–4·25; black, streak bnh; reacts for titanium. Black varieties of *brookite* (p. 163), submetallic in lustre, give same reaction.

Euxenite, p. 202; *yttrotantalite*, p. 202; *æschynite*, p. 202; *fergusonite*, p. 202, and *perofskite*, p. 163, are submetallic in lustre.

d. HEATED WITH NITRE IN A MATRASS YIELDS FUMES OF OSMIUM.

IRIDOSMINE, p. 127. H.=6-7; G.=19-21·2; in small scales from auriferous or platiniferous sands; tin-white, gyh.

V. LUSTRE UNMETALLIC.

1. MINERALS HAVING AN ACID, ALKALINE, ALUM-LIKE, OR STYPTIC TASTE.

A. CARBONATES: Taste alkaline; effervescing with H Cl.

NATRON, p. 229. Effloresces on exposure.

TRONA, p. 230. Does not effloresce.

B. SULPHATES : No effervescence; reaction B.B. on coal with soda for sulphur.

MASCAGNITE, p. 231. Yields ammonia.
MIRABILITE, p. 226. Monoclinic, crystals stout; taste cool, saline, bitter; B.B. flame deep yellow.
EPSOMITE, p. 205. Trimetric, crystals ordinarily slender, spicule-like; taste bitter and saline; B.B. flame not yellow.
ALUNOGEN, p. 197. Taste like common alum.
KALINITE, MENDOZITE and other alums, p. 198.
MELANTERITE, p. 182. Green; taste styptic; reacts for iron.
CHALCANTHITE, p. 137. Blue; reacts for copper.
MORENOSITE, p. 168. Green; reacts for nickel.
BIEBERITE, p. 168. Reddish; reacts for cobalt.
GOSLARITE, p. 156. White; reacts for zinc.
JOHANNITE, p. 171. Emerald-green, reacts for uranium.

C. NITRATES : With sulphuric acid, reddish acrid fumes; no action with hydrochloric acid; deflagrate.

NITRE, p. 228. Not efflorescent. Strong deflagration.
SODA-NITRE, p. 229. Efflorescent.
NITROCALCITE, p. 214. Deflagration slight.

D. CHLORIDES : With sulphuric acid acrid fumes of HCl; no fumes with HCl.

SALMIAK, p. 230. Taste saline, pungent; on coal, evaporates; with soda, odor of ammonia.
SYLVITE, p. 224. Taste saline; B.B. flame purplish.
HALITE or **COMMON SALT**, p. 224. Taste saline; B.B. flame yellow.

E. BORATES. No effervescence with acids; B.B. reaction for boron, when moistened with sulphuric acid.

SASSOLITE, p. 97. Taste feebly acid; B.B. very fusible.
BORAX, p. 227. Taste sweetish alkaline; B.B. puffs up.

2. MINERALS NOT HAVING AN ACID, ALKALINE, ALUM-LIKE OR STYPTIC TASTE.

A. CARBONATES: Effervescing with HCl.

A. INFUSIBLE; ASSAY ALKALINE AFTER IGNITION.

CALCITE, p. 215. H. under 3·5; G.=2·5-2·72; $R \wedge R = 105° 5'$, with three easy cleavages parallel to R; colors various; effervesces readily with cold HCl; anhydrous.

ARAGONITE, p. 218. H.=3·5–4; G.=2.94; **trimetric, cleavage imperfect; otherwise like calcite.**

DOLOMITE, p. 219. H.=3·5–4; G.=2·8–2·9; rhombohedral, $R \wedge R$ =106° 15′; colors various; **effervesces but slightly with *cold* HCl, unless finely pulverized; anhydrous.**

MAGNESITE, p. 207. H.=3·5–4·5; G.=3–3·1; rhombohedral, $R \wedge R$ =107° 29′; **white, ywh, gyh; effervesces but slightly with cold** HCl; anhydrous.

HYDROMAGNESITE, p. 207. H.=1–3·5; G.=2·14–2·18; **hydrous.**

B. INFUSIBLE; BECOME MAGNETIC AND NOT ALKALINE AFTER IGNITION.

SIDERITE, p. 185. H.=3·5–4·5; G.=3·7–3·9; **rhombohedral**, $R : R$ =107°; **cleavage as in calcite; becomes brown on exposure, changing to limonite.**

ANKERITE, p. 186. H.=3·5–4; G.=2·9–3·1; $R \wedge R$=106° 7′; **becomes brown on exposure.**

Some kinds of *calcite* and *dolomite* contain iron enough to become magnetic on ignition.

C. INFUSIBLE; B.B. ON COAL WITH SODA, COATING OF ZINC OXIDE.

SMITHSONITE, p. 156. H.=5; G.=4–4·5; **rhombohedral like calcite**; $R \wedge R$=107° 40′; **crystals often an acute rhombohedron; anhydrous.**

HYDROZINCITE, p. 157. H.=2–2·5; G.=3·6–3·8; **white, gyh, ywh, often earthy; reacts for zinc; hydrous.**

D. INFUSIBLE; B.B. ON COAL REACTION FOR NICKEL.

ZARATITE (Emerald nickel), p. 168. H.=3. Emerald **green, streak** paler.

E. FUSIBLE; ASSAY ALKALINE AFTER IGNITION.

WITHERITE, p. 221. H.=3–3·75; G.=4·29–4·35; **trimetric; white, ywh, gyh**; B.B. fuses easily, flame ywh green; anhydrous.

STRONTIANITE, p. 223 H.=3·5–4; G.=3·6–3·72; **trimetric; pale green, gray, ywh, white**; B.B. fuses only on thin edges, flame bright red; anhydrous.

BARYTOCALCITE, p. 222. Monoclinic. G.=3·6 3·66; B.B. **nearly** like witherite.

Other carbonates are the Lead Carbonate, p. 152, and Copper Carbonates, p. 140, included severally under the heads of LEAD and COPPER, on page 391.

B. SULPHATES or SULPHIDES: Reaction for Sulphur with Soda.

A. FUSIBLE; ASSAY ALKALINE AFTER FUSION.

BARITE, p. 220. H.=2·5-3·5; G.=4·3 4·72; trimetric; white, ywh, gyh, bluish, brown; B.B. decrepitates and fuses; flame yellowish-green; anhydrous.

CELESTITE, p. 222. H.=3-3·5; G.=3·9-3·98; trimetric; white, pale blue, rdh; B.B. fuses; flame red; anhydrous.

ANHYDRITE, p. 211. H.=3-3·5; G.=2·9-3·0; trimetric, with three rectangular and easy cleavages differing but slightly; white, bluish, gyh, rdh, red; B.B. fuses, flame reddish-yellow.

GYPSUM, p. 210. H.=1·5-2; G.=2·3-2·35; monoclinic, one perfect, pearly cleavage; white, gray, but also brown, black from impurities; B.B. yields much water, becomes white and crumbles easily.

B. FUSIBLE; REACTION FOR IRON.

COPIAPITE, p. 182. H.=1·5; G.=2·14; yellow; on coal, becomes magnetic; hydrous.

Haüynite, p. 270, also gives the sulphur reaction with soda.

C. INFUSIBLE, OR NEARLY SO.

ALUMINITE, p. 199. H.=1-2; G.=1·66; adheres to the tongue; white; B.B. blue with cobalt solution. **Alunite**, p. 198, is similar, but H.=4, and G.=2·58-2·75.

SPHALERITE, p. 154. H.=3·5-4; G.=3·9-4·2; isometric; light to dark resin-yellow; B.B. on coal, coating of zinc oxide.

C. ARSENATES: Arsenical fumes on coal.

SCORODITE, p. 185. H.=3·5-4; G.=3·1-3·3; trimetric; leek-green to liver-brown; B.B. fuses easily, flame blue, and with soda gives a magnetic bead; on coal alliaceous fumes; in HCl. sol.

PHARMACOSIDERITE, p. 185. H.=2·5; G.=2·9-3; cubes and tetrahedrons; dark green, bnh, reddish; B.B. same as for scorodite.

PHARMACOLITE, p. 214. H.=2-2·5; G.=2·6-2·75; wh, gyh, rdh; monoclinic with one eminent cleavage; B.B. fuses, flame blue; on coal, alliaceous fumes; after ignition assay alkaline; in HCl sol.

D. SILICATES, PHOSPHATES, OXIDES: SPECIES NOT INCLUDED IN THE THREE PRECEDING SUBDIVISIONS.

I. Streak deep red, yellow, brownish-yellow, green or black.

A. INFUSIBLE, OR FUSIBLE WITH MUCH DIFFICULTY.

HEMATITE, p. 176. Red to black; streak red; B.B. reaction for iron; magnetic after ignition in R.F.; anhydrous.
LIMONITE, p. 181. Brownish and ochre-yellow to black; streak brownish-yellow; B.B. gives off water, turns red, becomes magnetic in R.F.
TURGITE, p. 182. Brown to black; streak red; B.B. gives off water; decrepitates; becomes magnetic in R.F.
FERGUSONITE, p. 202. Brownish black; infusible.
ZINCITE, p. 155. Red; streak orange; B.B. on coal, zinc oxide coating, and coating moistened with cobalt solution, green in R.F.

B. FUSIBLE WITHOUT MUCH DIFFICULTY.

WOLFRAMITE, p. 183. Grayish to brownish black; streak dark reddish brown to black; lustre submetallic; G.=7·1–7·55. B.B. fuses easily, and becomes magnetic; reaction for tungsten.
VIVIANITE, p. 184. Blue to green (to white); streak bluish-white; G.=2·5–2·7; H.=1·5–2, hydrous; B.B. fuses easily to magnetic globule, coloring flame bluish-green.
TORBERNITE, p. 170. Bright green, square tabular micaceous crystals; streak paler green; H.=2–2·5; hydrous; yields a globule of copper with soda.
SAMARSKITE, p. 202. H.=5·5–6; G.=5·6–5·8; velvet-black; streak dark reddish brown; B.B. fuses on the edges.

II. Streak grayish or not colored.

1. INFUSIBLE.

A. GELATINIZE WITH ACID, FORMING A STIFF JELLY.

CHRYSOLITE, p. 255. Yellow-green to olive-green, looking like glass; H.=6·7; G.=3·3–3·5; B.B. reacts for iron, becomes magnetic; anhydrous.
CHONDRODITE, p. 281. H.=6–6·5; G.=3·1–3·25; pale yellow to brown, and reddish-brown; lustre vitreous to resinous; B.B. reaction for iron and fluorine; anhydrous.
ALLOPHANE, p. 296. H.=3; G.=1·8–1·9; always amorphous, never granular in texture; bluish, greenish; B.B. infus., a blue color with cobalt solution; hydrous.

Willemite, *Calamine*, *Sepiolite*, fuse with great difficulty, and are included under fusible gelatinizing species, p. 402.

B. NOT FORMING A STIFF JELLY WITH ACID ; HYDROUS.

a. **Blue with cobalt solution** (owing to presence of aluminum).

WAVELLITE, p. 201. H.=3·25–4 ; G.=2·3–2·4 ; white to green, brown ; B.B. bluish-green flame after moistening with sulph. acid.

LAZULITE, p. 199. H.=5·6 ; G.=3-3·1 ; blue ; B.B. green flame, especially after moistening with sulph. acid ; hydrous.

TURQUOIS, p. 200. H.=6 ; G.=2·6–2·85 ; sky-blue, pale green ; B.B. flame green.

KAOLINITE, p. 310. H.=1–2 ; G.=2·4–2·65 ; white when pure ; feel greasy ; B.B. flame not green.

GIBBSITE, p. 194. H.=2·5–3·5 ; G.=2·3–2·4 ; white, grayish, greenish ; B.B. flame not green ; soluble in strong sulph. acid.

DIASPORE, p. 194. H.=6·5–7 ; G.=3·3–3·5 ; in thin foliated crystals, plates or scales ; white, greenish, brownish ; B.B. flame not green ; soluble in sulphuric acid *after* ignition.

b. **Pale red or pink color, with cobalt solution** (owing to presence of magnesium).

BRUCITE, p. 204. H.=2·5 ; G.=2·3–2·45 ; pearly, white, greenish ; foliaceous or fibrous and flexible ; B.B. after ignition, alkaline.

c. **Not blue or red with cobalt solution.**

OPAL, p. 239. H.=5·5–6·5 ; G.=1·9–2·3 ; B.B. with soda soluble with effervescence.

GENTHITE, p. 309. H.=3–4 ; G.=2·4 ; pale green, yellowish ; B.B. with borax a violet bead, becoming gray in R.F. owing to nickel ; decomp. by H Cl.

CHRYSOCOLLA, p. 142. H.=2–4 ; G.=2-2·24 ; pale bluish-green to sky-blue ; B.B. flame emerald-green, and with soda on coal globule of copper.

The micas, chlorites, chloritoid, and serpentine often fuse on their edges with *much* difficulty.

C. NOT FORMING A STIFF JELLY ; ANHYDROUS. H.=5 to 9.

a. **Blue color with cobalt solution.**

CORUNDUM, p. 192. H.=9 ; G.=4 ; rhombohedral ; blue, white, red, gray, brown.

CHRYSOBERYL, p. 196. H.=8·5 ; G.=3·7 ; gray, green, to emerald-green.

TOPAZ, p. 286. H.=8 ; G.=3·5 ; in rhombic prisms with perfect basal cleavage, rarely columnar ; white, wine-yellow, and other shades.

RUBELLITE, p. 283. H.=7·5 ; G.=3 ; in prisms of 3, 6, or 9 sides ; rose-red ; reaction for boron.

ANDALUSITE, p. 284. H.=7·5 ; G.=3·2 ; always in prismatic crystals, often tesselated within, $I \wedge I = 93^\circ$; grayish-white to brown.

FIBROLITE, p. 285. H.=6–7 ; G.=3·2 ; columnar or fibrous forms and prismatic crystals with brilliant diag. cleavage.

CYANITE, p. 286. H.=5–7 (greatest on extremities of crystals); G.=3·6; in long or short prismatic crystallizations, often bladed prisms; pale blue to white and gray.

LEUCITE, p. 271. H.=5·5–6; G.=2·5; white, gyh; often in trapezohedral crystals.

b. Not giving a blue or reddish color with cobalt solution; H.= 8 to 5.

SPINEL, p. 194. H.=8; G.=3·5–4·1; in octahedrons of red, greenish, gray, black colors. *Gahnite* is similar, but with borax on coal, gives reaction for zinc.

BERYL, p. 252. H.=7·5–8; G.=2·6–2·7; always in hexagonal prisms; pale bluish and yellowish green, to emerald-green, also resin yellow and white, no distinct cleavage.

ZIRCON, p. 259. H.=7·5; G.=4–4·75; dimetric, and often in square prisms; lustre adamantine; brown, gray.

STAUROLITE, p. 291. H.=7; G.=3·4–3·8; in prisms of 123°, and often in cruciform twins; no distinct cleavage; brown, black, gray.

QUARTZ, p. 233. H.=7; G.=2·6; often in hexagonal crystals with pyramidal terminations; of various shades of color. OPAL, p. 239, is in part anhydrous.

MONAZITE, p. 203. H.=5–5·5; G.=4·9–5·3; in small brown imbedded monoclinic crystals, with perfect basal cleavage; B.B. flame bluish-green when moistened with sulph. acid.

RUTILE, p. 162. H.=6–6·5; G.=4·15–4·25; dimetric; reddish-brown to brownish-red, green, black; B.B. reaction for titanium. BROOKITE and OCTAHEDRITE, p. 163, are similar, except in crystalline forms, and G. in brookite 4·0–4·25, in octahedrite 3·8–3·95.

PEROFSKITE, p. 163. H.=5·5; G.=4–4·1; yellowish, brown, black; cubic and octahedral forms; B.B. reaction for titanic acid.

ENSTATITE, p. 244. H.=5·5; G.=3·1–3·3; in prismatic and fibrous forms with $I \wedge I$=88° 16′, also foliated; whitish, grayish, brown. *Anthophyllite* is similar, but $I \wedge I$=125°, and it fuses on the edges with great difficulty.

Iolite, apatite, scheelite, euclase, fuse with much difficulty, and euclase gives some water in closed tube when highly ignited.

2. FUSIBLE WITH LITTLE OR MUCH DIFFICULTY.

A. Gelatinize and afford a Stiff Jelly.

a. Hydrous; fuse easily.

DATOLITE, p. 289. H.=5–5·5; G.=2·8–3; white, greenish, yellowish; crystals glassy, stout, sometimes massive and porcellanous, never fibrous; B.B. fuses easily, reaction for boron.

NATROLITE, p. 299. H.=5–5·5; G.=2·3–2·4; in slender rhombic prisms, and divergent columnar; white, ywh, rdh, red; B.B. fuses very easily.

SCOLECITE, p. 299. H.=5–5·5; G.=2·16–2·4; cryst. much like natrolite, but twinned, with converging striæ on *i-ì* as in figure on p. 299; B.B. sometimes curls up, fuses very easily.

GMELINITE, p. 301. H.=4·5; G.=2–2·2; in small and short hexagonal or rhombohedral cryst.; B.B. fuses easily.

PHILIPPSITE, p. 302. H.=4–4·5; G.=2·2; in twinned crystals; B.B. fuses rather easily.

LAUMONTITE, p. 293. H.=3·5–4; G.=2·2–2·4; white, reddish; crystals become white and crumbling on exposure to the air; B.B. fuses rather easily.

Pectolite (p. 293), and *Analcite* (p. 299), imperfectly gelatinize.

b. Hydrous; fuse with much difficulty.

CALAMINE, p. 157. H.=4·5–5; G.=3·15–3·19; white, greenish, bluish; orthorhombic in crystals; B.B. fus. with great difficulty, reaction for zinc and none for iron; hydrous.

SEPIOLITE, p. 306. White; soft and almost clay-like, also fibrous; B.B. fuses with difficulty, with cobalt solution reddish; hydrous.

PYROSCLERITE, p. 317. H.=3; G.=2·74; micaceous; B.B. fuses on thin edges.

c. Anhydrous.

α NO REACTION FOR SULPHUR; NO COATING ON COAL.

NEPHELITE, p. 269. H.=5·5–6; G.=2·5–2·65; hexagonal prisms and massive; vitreous, with greasy lustre; white, ywh, gyh brown, rdh; B.B. fuses rather easily.

WOLLASTONITE, p. 244. H=4·5–5; G.=2·75–2·9; white, gyh, rdh, bnh; B.B. fuses easily.

SODALITE, p. 270. H.=5·5–6; G.=2·13–2·4; white, blue, reddish; in dodecahedrons and massive; B.B. fuses not very easily.

WILLEMITE, p. 157. H.=5·5; G.=3·9–4·3; white to greenish, reddish, brownish; B.B. glows and fuses with difficulty; reaction for zinc and none for iron; anhydrous.

β. REACTION FOR SULPHUR B.B. WITH SODA.

HAUYNITE, p. 270. H.=5·5–6; G.=2·4–2·5; blue, greenish; isometric, in dodecahedrons, octahedrons; B.B. fuses with some difficulty.

DANALITE, p. 256. H.=5·5–6; G.=3·427; isometric; flesh-red to gray; B.B. fuses rather easily, and gives reaction for manganese and zinc.

B. Not Gelatinizing.

1. STRUCTURE EMINENTLY MICACEOUS, SURFACE OF FOLIA MORE OR LESS PEARLY; H. OF SURFACE OF FOLIA NOT OVER 3·5; ANHYDROUS OR HYDROUS.

MUSCOVITE, BIOTITE, PHLOGOPITE, LEPIDOLITE, LEPIDOMELANE: for distinctions see pp. 266–268. Anhydrous, or affording very little water; B.B. fuse with difficulty on thin edges, excepting lepidomelane which fuses rather more easily.

MARGARODITE, DAMOURITE, p. 313. Much like common mica, but more pearly and greasy to the feel, folia not elastic; giving a little water in the closed tube; color usually whitish.

PENNINITE, RIPIDOLITE, PROCHLORITE, p. 318. Usually bright or deep green, blackish-green, reddish, rarely white; folia tough, inelastic; B.B. diff. fus., reaction for iron and yield much water; partially decomposed by acids.

VERMICULITE, JEFFERISITE, p. 317. Brown, yellowish-brown, green; exfoliate remarkably; yield much water.

MARGARITE, p. 319. H.=3·5–4·5 (highest on edges); G.=2·99; white, ywh, rdh; folia somewhat brittle; B.B. fuses on thin edges; yields a little water.

TALC, p. 304. H.=1–1·5; G.=2·5–2·8; pearly and very greasy to the touch; white, pale green, gray; B.B. very difficultly fusible, yields usually traces of water; reddish with cobalt solution.

PYROPHYLLITE, p. 306. Similar to talc; but B.B. exfoliates remarkably; blue with cobalt solution.

FAHLUNITE, p. 314, has often a more or less distinct micaceous structure.

Autunite, p. 170, has a mica-like basal cleavage; but it occurs in small square tables of a bright yellow color. *Diallage,* p. 246, has a structure nearly micaceous. *Serpentine* is sometimes nearly micaceous, but the folia are not easily separable and are brittle. *Chloritoid* has a perfect basal cleavage, but folia very brittle, and cleavage less easily obtained than in the preceding; and moreover the mineral is infusible.

2. STRUCTURE NOT MICACEOUS.

a. Hydrous.

α. NO REACTION FOR PHOSPHORUS, OR BORON.

† Hardness, with the exception of a variety of serpentine, 1 to 3; lustre not at all vitreous.

CHLORITES, p. 318. H.=2–2·5. Here fall the massive granular chlorites, olive-green to black in color, of the species *penninite, ripidolite, prochlorite;* B.B. reaction for iron, fuses with difficulty; yields much water.

VERMICULITE, p. 317. H.=1–1·5. Granular massive forms of vermiculite.

TALC, p. 304. H.=1–1·5. Here falls steatite (soapstone) or massive talc, of white to grayish green and dark green color, granular to cryptocrystalline in texture. B.B. fuses with great difficulty, and yields only traces of water; no reaction for iron, or only slight.

PYROPHYLLITE, p. 306. Grayish white, massive or slaty; B.B. like the crystallized, p. 403, in its difficult fusibility and little water yielded, but does not exfoliate.

SERPENTINE, p. 307. H.=2·5–4; G.=2·36–2·55; olive-green; ywh green; blackish green, white; B.B. fuses with difficulty on thin edges; yields much water.

PINITE, p. 312. H.=2·5–3·5; G.=2·6–2·85; lustre feebly waxy; gray, gnh, bnh. B.B. fuses; yields water.

DAMOURITE, p. 313. Same as crystallized, p. 403, but in massive aggregation of scales.

†† **Hardness 3·5 to 6·5; lustre often pearly on a cleavage surface, but elsewhere vitreous.**

PREHNITE, p. 295. H.=6–6·5; G.=2·8–3; pale green to white; crystals often barrel-shaped, made of grouped tables; B.B. fuses very easily; decomp. by H Cl.

PECTOLITE, p. 293. H.=5; G.=2·68–2·8; white; divergent fibrous, or acicular; B.B. fuses very easily; gelatinizes imperfectly with H Cl.

APOPHYLLITE, p. 294. H.=4·5–5; G.=2·3–2·4; white, gnh, ywh, rdh; dimetric, one perfect pearly cleavage transverse to prism; B.B. fuses very easily; a fluorine reaction; decomp. by H Cl.

CHABAZITE, p. 300. H.=4–5; G.=2–2·2; rhombohedral, vitreous; white, rdh; B.B. fuses easily; decomp. by H Cl.

HARMOTOME, p. 301. H.=4·5; G.=2·44; white, ywh, rdh; crystals twins, usually cruciform; B.B. fuses not very easily; vitreous in lustre; decomp. by H Cl.

STILBITE, p. 302. H.=3·5–4; G.=2–2·2; white, ywh, red; crystallizations often radiated-lamellar; one perfect pearly cleavage; B.B. exfoliates, fuses easily; decomp. by H Cl.

HEULANDITE, p. 303. H.=3·5–4; G.=2·2; in oblique crystals, with one perfect pearly cleavage; B.B. same as for stilbite.

EUCLASE, p. 288. H.=7–5; G.=3·1: in glassy transparent monoclinic crystals; B.B. fuses with great difficulty; gives water in closed tube *when strongly ignited.*

Prehnite, apophyllite, chabazite, harmotome, heulandite, and *euclase* never occur in fibrous forms.

β. REACTION EITHER FOR PHOSPHORUS OR BORON.

VIVIANITE, p. 184. H.=1·5–2; G.=2·55–7; monoclinic with one perfect cleavage; white, blue, green; B.B. fuses very easily, the flame bluish green, a gray magnetic globule; in H Cl sol.

ULEXITE, p. 212. H.=1; G.=1·65; white, silky, in fine fibres; B.B. fuses very easily, and moistened with sulph. acid flame for an instant green, owing to the boron present; little sol. in hot water. PRICEITE (p. 212) is in texture and color like chalk; similar to ulexite in green flame B.B.

Borax and *Sassolite* are other soft minerals containing boron, but these have *taste.*

b. Anhydrous.

α. **B.B. the flame lithium-red.**

SPODUMENE, p. 248. H.=6·5–7; G.=3·13–3·19; white, gyh, gnh white, monoclinic (like pyroxene), with $I \wedge I = 87°$, and perfect cleavage parallel to *I* and *i-i*; B.B. swells and fuses.

PETALITE, p. 248. H.=6–6·5; G.=2·4–2·5; white, gray, rdh, gnh; B.B. becomes glassy and fuses only on the edges.

HEBRONITE, AMBLYGONITE, p. 199. H.=6; G.=3–3·1; mountain green, gyh, white, bnh; B.B. fuses very easily, reaction for fluorine.

TRIPHYLITE, p. 190. H.=5; G.=3·5–3·6; greenish gray, bluish, often bnh black externally; B.B. fuses very easily, globule magnetic; with soda, manganese reaction.

LEPIDOLITE, p. 268. H.=2·5–4; G.=2·8–3; micaceous, also scaly-granular; rose-red, pale violet, white, gyh; B.B. fuses easily; after fusion gelat. with H Cl. Some *biotite*, p. 266, gives the lithia reaction.

β. B.B. boron reaction (green flame).

TOURMALINE, p. 282. H.=7; G.=2·9–3·3; rhombohedral, prisms with 3, 6, 9 sides, no longitudinal or other distinct cleavage; black, blue black, green, red, rarely white; lustre of dark var. resinous; B.B. fusion easy for dark var. and diff. for light.

AXINITE, p. 264. H.=6·5–7; G.=3·27; triclinic, sharp-edged, glassy crystals; rich brown to pale brown and grayish; B.B. fuses readily; with borax violet bead.

BORACITE, p. 206. H.=7; G.=2·97; isometric; white, gyh, gnh; lustre vitreous; fuses easily, coloring flame green.

Danburite, p. 264, is another boron silicate.

γ. B.B. reaction for titanium.

TITANITE, p. 290. H.=5–5·5; G.=3·4–3·56; monoclinic; usually in thin sharp-edged crystals; brown, ywh, pale green, black; lustre usually subresinous; B.B. fuses with intumescence.

δ. Reaction for fluorine or phosphorus.

CRYOLITE, p. 197. H.=2·5; G.=2·9–3; white, rdh, bnh; *fuses in the flame of a candle;* soluble in sulph. acid which drives off hydrogen fluoride, a gas that corrodes glass.

FLUORITE, p. 208. H.=4; G.=3–3·25; isometric, with perfect octahedral cleavage, and massive; white, wine-yellow, green, purple, rose-red, and other bright tints; phosphoresces; when heated, decrepitates; B.B. fuses, coloring the flame red; after ignition, alkaline.

Lepidolite (p. 268), *Amblygonite* (p. 199), also give a fluorine reaction.

APATITE, p. 212. H.=4·5–5; G.=2·9–3·25; often in hexagonal prisms; pale green, bluish, yellow, rdh, bnh, pale violet, white; B.B. fuses with difficulty, moistened with sulph. acid and heated, flame bluish green from presence of phosphorus; sometimes reaction for fluorine.

ε. Reaction for iron.

GARNET, p. 256. H.=6·5–7·5; G.=3·15–4·3; isometric, usually in dodecahedrons and trapezohedrons, also massive, never fibrous or columnar; red, bnh red, black, cinnamon-red, pale green, to emerald-green, white. B.B. dark-colored varieties fuse easily, and give iron reaction, but emerald-green var. almost infusible; a white to yellow massive garnet is hardly determinable without chemical analysis.

VESUVIANITE (Idocrase), p. 261. H.=6·5; G.=3·35-3·45; dimetric and often in prisms of four or eight sides, never fibrous; brown to pale green, ywh, bk; B.B. fuses more easily than garnet; reaction for iron.

EPIDOTE, p. 262. H.=6-7; G.=3·25-3·5; in monoclinic cryst. and massive, rarely fibrous; unlike amphibole in having but one cleavage direction; ywh green, bnh green, black, rdh, yellow, dark gray; B.B. fuses with intumescence.

AMPHIBOLE, dark varieties including *hornblende*, *actinolite*, and other green to gray and black kinds, p. 249. H.=5·6; G.=3-3·4; monoclinic, in short or long prisms, often long fibrous, lamellar, and massive, prisms usually four or six sides, $I \wedge I = 124\frac{1}{2}^\circ$, cleavage par. to I; B.B. fusion easy to moderately difficult.

ANTHOPHYLLITE, p. 252, like hornblende; bnh gray to bnh green, sometimes lustre metalloidal; B.B. fuses with great difficulty.

PYROXENE, *augite*, and all green to black varieties, p. 245. H.=5-6; G.=3·2-3·5; monoclinic, in short or oblong prisms, lamellar, columnar, not often long, fibrous or asbestiform, prisms usually with four or eight sides, $I \wedge I = 87^\circ\ 5'$, cleavage par. to I; B.B. as in hornblende.

HYPERSTHENE, p. 244. H.=5-6; G.=3·39; cryst. nearly as in pyroxene, but trimetric, usually foliated massive, also fibrous; bnh green, gyh black, pinchbeck-brown; B.B. fuses with more or less difficulty. *Bronzite*, p. 244, is similar and almost infusible.

IOLITE, p. 264. H.=7-7·5; G.=2·6-2·7; blue to blue violet; looks like violet-blue glass; B.B. fuses with much difficulty.

Tourmaline, much *Titanite*, and *Ilvaite* (p. 263), B.B. give iron reaction.

ζ. No reaction for iron.

SCHEELITE, p. 212. H.=4·5-5; G.=5·9-6·1; ywh, gnh, rdh, pale yellow; lustre vitreous-adamantine; fuses on the edges with great difficulty.

SCAPOLITES, p. 268. H.=5·5-6; G.=2·6-2·74; dimetric, often in square prisms; white, gray, gnh gray; B.B. fuses easily with intumescence.

ZOISITE, p. 263. H.=6-6·5; G.=3·1-3·4; trimetric, oblong prisms and lamellar massive, cleavage in only one direction.

AMPHIBOLE, *white var.* (*tremolite*), p. 249. Same as for other amphibole (above), except in color; B.B. fuses

PYROXENE, *white var.*, p. 215. Same as for other pyroxene (above), except in color; B.B. fuses.

ORTHOCLASE, p. 278. H.=6-6·5; G.=2·4-2·62; monoclinic, stout cryst., and massive, never columnar, two unequal cleavages, the planes at right angles with one another, and cleavage surfaces never finely striated, as seen under a pocket lens or microscope; white, gray, flesh-red, bluish, green; B.B. fuses with some difficulty.

ALBITE, p. 277, **OLIGOCLASE**, p. 276. H.=6 ; G.= triclinic, but cryst. as in orthoclase, except that the two planes make an angle of 93½° to 94°, and one of them has th striated ; white usually, flesh-red, bluish ; B.B. fuse with difficulty ; not acted on by acids.

LABRADORITE, p. 276. H.=6 ; G.=2·66–2·76 ; triclinic, li in cryst., and nearly in cleavage angle, 93° 20′, and in surface ; white, flesh-red, bnh red, dark gray, gyh brow fuses easily ; decomposed by HCl with difficulty.

ANORTHITE, p. 275. H.=6–7 ; G.=2·66–2·78 ; cryst. a as in albite, cleavage angle 94° 10′ ; white, gyh, rdh ; B.B difficult ; decomposed by HCl with separation of gelat. silic

MICROCLINE, p. 278. Very near orthoclase in all charact triclinic, cleavage angle differing only 16′ from a right an surface of most perfect cleavage striated, but striæ exc fine, often difficult to detect with a good pocket lens, and r the aid of a polariscope ; color white, gray, flesh-red, often

For optical distinctions of **FELDSPARS**, see p. 274.

EUCLASE, p. 288. H.=7·5 ; G.=3·1 ; in monoclinic crysta one perfect diagonal cleavage ; pale green to white, bnh parent ; becomes electric by friction.

ON ROCKS.

I. CONSTITUENTS OF ROCKS.

ROCKS are made up of minerals. A few kinds consist of a single mineral alone: as, for example, *limestone*, which may be either the species calcite or dolomite; *quartzyte* (along with much sandstone), which is quartz; and *felsyte*, which is orthoclase. But even these simple kinds are seldom free from other ingredients, and often contain visibly other minerals. Nearly all kinds of rocks are combinations of two or more minerals. They are not definite compounds, but indefinite mixtures, and hardly less indefinite than the mud of a mud-flat. The limits between kinds of rocks are consequently ill-defined. Granite graduates insensibly into gneiss, and gneiss as insensibly into mica schist and quartzyte, syenyte into granite, mica schist into hornblende schist, granite also into a compact porphyry-like rock, and trachyte; and so it is with many other kinds. The fact is a chief source of the difficulty in studying and defining rocks, and especially the crystalline kinds. The different rocks are not *species* in the sense in which this word is used in science, but only *kinds* of rocks.

The minerals which are the chief constituents of rocks are of two classes: (A) the *Siliceous;* (B) the *Calcareous.*

A. The siliceous are as follows:

1. *Quartz*, which probably makes up one-third of the rocky material of the crust of the globe.

2. The *Feldspars* (p. 272); of which *orthoclase* (with microcline) is most abundant; next to it, *oligoclase* and *labradorite;* and next *albite, andesite,* and *anorthite.*

3. The *Micas* (p. 265): *muscovite* and *biotite*, of equal prominence, the others much less common.

4. *Amphibole* and *Pyroxene* species (p. 245, and beyond): especially *hornblende* or black amphibole, and *augite* or

black pyroxene; also the green hornblende or *actinolite;* the green foliated hornblende called *smaragdite,* and the foliated pyroxene sometimes wrongly called *hypersthene,* and another variety called *diallage;* also occasionally the species *hypersthene* and *enstatite.*

5. The Feldspar-like minerals, *nephelite* (p. 269) and *leucite* (p. 271), which are related in constituents and quantivalent ratios to the feldspars, alumina being the only sesquioxide base, and lime, potash, and soda the protoxide bases afforded in analyses; the atomic ratios for the protoxides, sesquioxide, and silica being in nephelite, 1 : 3 : 4, as in anorthite; and in leucite 1 : 3 : 8, as in andesite. Also, less abundantly, *Sodalite* (p. 270), which has essentially the ratio of anorthite and nephelite.

6. *Minerals of the Saussurite group.* These jade-like species differ from the feldspars—(1) in being always fine-granular in texture; (2) in having a high density, G.= 2·9–3·4; in varying from the feldspar type chemically. They are near some soda-lime feldspars in constituents, but not always in the atomic relations of the constituents, nor in the absence uniformly of magnesia. There are two prominent kinds. *One* is between anorthite and zoisite in composition (see p. 263); yet, unlike these minerals, its analyses afford several per cent. of soda and some magnesia. The *second* approaches labradorite; Delesse obtained for a specimen from Mt. Genèvre (Alps), Silica 49·73, alumina 29·65, iron protoxide 0·85, magnesia 0·56, lime 11·18, soda 4·04, potash 0·24, water (with a little CO_2) 3·75; and a Silesian specimen afforded Vom Rath nearly the same result. A *third* kind from Corsica, according to Boulanger's analysis, has nearly the same composition as zoisite. A *fourth* is jadeite (p. 263), a stone occurring in the Swiss lake-dwellings—but not yet found in the saussurite rocks of Switzerland.

The saussurite of Siberia and the Alps has been observed to have sometimes the form of twins of a triclinic feldspar. This, and the texture, density, and composition, show that saussurite is, in part at least, pseudomorphous, and, in some regions, after labradorite. By some peculiar conditions in the process of metamorphism—perhaps long-continued heat with an unusual amount of moisture—the feldspar crystallizations that formed in the incipient stages of the process were afterward changed to a species of higher density and different molecular nature ; in other words, to saussurite. Some of the material appears to be still labradorite.

7. The iron-bearing minerals, *Epidote* (p. 262), *Garnet* (p. 256), *Chrysolite* (p. 255), which characterize some varieties of rocks.

B. The *calcareous* species are *calcite* or calcium carbonate (p. 215), in various states of impurity ; and *dolomite* or calcium-magnesium carbonate (p. 219), which in its rock-form is undistinguishable in external aspect from calcite.

Gypsum, or hydrous calcium sulphate, is also a constituent of beds among rocks, and should have its place in the list, although not strictly embraced under the term calcareous.

Of the siliceous minerals, orthoclase (with microcline), and the two micas, muscovite and biotite, are related in composition, in that each affords 10 per cent. or more of potash. Leucite is another allied potash-alumina silicate, even richer in potash than orthoclase, it containing 17 to 21 per cent. The rocks characterized by these minerals are hence rich in potash.

Albite and oligoclase, and also sodalite, afford much soda, the first two usually 8 to 12 per cent., and sodalite, 20 to 25 per cent. Nephelite (elæolite) is also a soda mineral related to the feldspars ; but, with 15 to 16 per cent. of soda, there are 5 or 6 of potash ; rarely the alkali afforded is all soda.

The ordinary kinds of hornblende and pyroxene, on the contrary, afford little or no soda or potash. They thus differ widely from the potash and soda species just mentioned, and naturally characterize for the most part a distinct series of rocks.

Much importance has been allowed in lithology to the distinction of *foliated* under the species hornblende and pyroxene ; when, in fact, neither in mineralogy, as all treatises admit, nor in lithology, has it more than a very subordinate value. The character obtained this distinction before it was fully understood that the foliated forms were identical in composition with those in crystals or in massive forms.

Hornblende does not differ from augite in composition ; but since the difference in crystallization is connected with a difference in the physical conditions attending their origin, and since rocks of each kind often have a vast extent over the earth's surface, the distinction as to whether a rock is hornblendic or augitic is of prominent geological interest.

II. CLASSES OF ROCKS.

Rocks are of different classes, according to their texture and origin.

1. FRAGMENTAL. A large part of common rocks were formed of sand, or pebbles and sand, and are only consolidated sand-beds or gravel-beds; and other related kinds are more or less consolidated mud-beds or clay-beds. The mud-beds of an estuary, or of the shallow seas off a coast, and the stratified sand and gravel accumulations of sea-shores and valley formations, are precisely the kind of material which by consolidation have made the fragmental rocks, the most abundant rocks of the earth's surface. Each pebble, grain of sand, and constituent particle of the mud, was derived from preëxisting rocks, and is either an actual fragment from those rocks, or else a fragment altered by more or less complete decomposition. The rocks are hence called *fragmental.* The pebbles, and often the sands, have a worn surface, and this fact, together with the structure of the beds, affords evidence that they are fragmental. They are also the ***sedimentary*** rocks of geology; for the material was for the most part carried and dropped by waters as sediment is carried and dropped—the waters mainly of the ocean which then covered the continents.

2. CRYSTALLINE. Other rocks are crystalline. The grains are angular instead of worn, and they crowd upon or penetrate one another because made in one process of crystallization. They are generally angular over a fractured surface because of the cleavage planes, like the grains of a surface of broken iron. Granite, trap, white marble are examples of crystalline rocks. When such a rock is distinctly granular there is little difficulty in deciding upon its being a crystalline rock. If too fine-grained for a positive conclusion with the aid of a pocket-lens, the doubt may usually be removed by tracing it along to places where it is coarser; and if none such offers, by the preparation of thin slices for microscopic examination.

Crystalline rocks have received their crystalline texture in different ways.

A. By cooling from fusion. The rocks thus made are called IGNEOUS or ERUPTIVE rocks, as, for example, lavas or volcanic ejections, and all rocks that, like trap, have come up melted through fissures in the earth's rocky crust. The depth of the liquid source of such eruptions is unknown. The fact that, at one epoch, material of the same kind has sometimes been ejected at intervals along a band of country a thousand miles in length, from northeast to southwest, as on the Atlantic coast from Nova Scotia to South Carolina, indicates considerable depth in such cases. They may be older rocks melted over and thrust up to the surface ; but if so, the remelted rocks were in many cases those situated deep in the earth's crust, far below all the strata of its surface.

B. By subjection to long-continued heat without fusion, making METAMORPHIC rocks. Through this means fragmental or sedimentary strata, over areas of thousands of square miles, and many thousands of feet in depth, have been simultaneously crystallized, turning the beds that were originally made from sand, gravel, or mud, into granite, gneiss, and other related rocks, and compact limestones into marble. The rocks at the time of the change were generally undergoing extensive mountain-making uplifts, and it is supposed that the friction attending the movements of the strata may have been an important source of heat for the change or crystallization ; and that the diffusion of this heat was due to the moisture which abounds in unaltered sedimentary beds. Metamorphic strata retain their former relative order of superposition, having been crystallized *in place,* that is, without fusion. Where granite has been the result, it is probable that the material was sometimes reduced to a pasty state, so that all lines of the original bedding were obliterated ; but even in that case, the granite is generally in the place occupied by the material before crystallization. In other cases, including that of some granites, there was not even this degree of approach toward the original condition of the true eruptive rock. During the upturning, the rocks were much fractured, and the fissures so made became filled with the materials of the adjoining or subjacent rocks, through the aid of the heated moisture present, making veins ; and such veins differ widely from those, called *dikes,* that were made when the fractures descended to regions of melted rock, so that the fissures became filled with ejected material.

Rocks thus metamorphosed or rendered crystalline are distinguished as *metamorphic* rocks.

C. By *chemical deposition.* Waters often hold calcareous material in solution. When carbonic acid (carbon dioxide) is present in any waters, those waters will take up calcium carbonate, and make calcium bicarbonate; and when the waters evaporate, the calcium carbonate is deposited. This is the process by which stalactites and stalagmites (p. 216) have been made, and so also calcareous tufa and travertine (p. 432). The Gardiner River region in the Yellowstone Park is noted for its deposits of travertine.

In geyser regions there are siliceous deposits made by the hot waters, as stated on page 240; and these also are exemplified in the Yellowstone Park.

Beds of tripolite (p. 241) sometimes become consolidated and converted into chert by the waters that penetrate them —these waters containing a trace of alkali or enough to enable them to dissolve some of the tripoli silica, and then a deposition taking place causing consolidation. The flint and chert of the rocks has probably had generally this origin.

3. CALCAREOUS ROCKS OR LIMESTONES. Compact limestones are commonly of fragmental origin. They have been made mainly out of worn or ground-up shells, corals, and like calcareous material of organic origin—the movements of the ocean having been, and still being, the grinding agency. They were consolidated through the ocean's waters which penetrated the beds taking up a little calcareous material, and then depositing it again. It is, in one sense, metamorphism. But when such compact limestones experience true metamorphism, at the same time with other strata, they become distinctly crystalline-granular, and often very coarsely so, making crystalline limestone or marble.

III. ON SOME CHARACTERISTICS OF ROCKS.

1. CRYSTALLINE TEXTURE. Crystalline texture varies in coarseness from that in which crystalline grains are visible only under high magnifying power, and the rock is as aphanitic (p. 60) as flint, to that in which they are very coarse. Not unfrequently one of the minerals appears in large crystals, distributed through the mass—the mass being made of

the rest of the material in a comparatively fine-grained condition. The porphyry of the ancients was a rock of dark feldspathic base, sprinkled all through with light-colored feldspar crystals; and, from this fact, any metamorphic or igneous rock containing such disseminated crystals of a feldspar is said to be *porphyritic.*

The following figures illustrate three varieties of porphyritic rock. The first represents a specimen of the *red antique porphyry* of Egypt—now often called *Rosso antico*—the rock which gave the name porphyry to geology, a kind much used by the Romans (though not by the Greeks or Egyptians), and quarried by them in the mountain Djebel-Dokhan, twenty-five miles from the Red Sea, in latitude 27° 20′. Through the red aphanitic base small whitish crystals of orthoclase are thickly distributed. Figure 2 is from a polished piece of *green antique* poryphyry. The feldspar crystals are comparatively large, and the compact base has a dark green color. Figure 3 represents a large crystal of orthoclase with the gneiss about it, from porphyritic gneiss. The feldspar crystals in porphyritic gneiss or granite sometimes measure three inches by one and a half, and again only a fraction of an inch. These orthoclase crystals, as often in other porphyritic rocks, are twin crystals, the plane of cleavage of one half making an angle of 52° 23′ with that of the other half. Occasionally large crys-

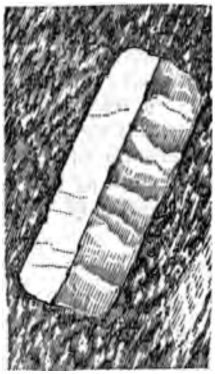
1.

Rosso Antico.

2.

Oriental Verd-antique.

3.



Porphyritic gneiss.

tals contain small crystals of mica distributed in one or more layers concentric with the sides.

The degree of coarseness in the texture of a crystalline rock has been determined chiefly by the rate of cooling, in connection with the nature of the material. Relatively rapid cooling produces a fine texture or grain, and very slow cooling a coarser.

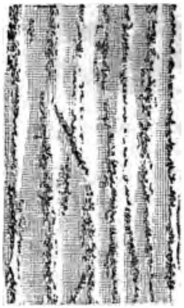
A melted rock may cool too rapidly to become stony throughout, or to become stone at all; and, in the latter case, the material made is glass. Common melted glass would be stone on cooling if the process were gradual enough.

Figures 4 to 6 represent much-magnified views afforded by transparent slices from glassy rocks, in three of their stages between the pure glassy and the true stony state. In 4, from obsidian, or volcanic glass, of Greenland, there are radiating clusters consisting of hair-like *microlites* (or microscopic minerals), called *trichites* (from the Greek *thrix*, hair), such as are common in all obsidians. Fig. 5 shows the texture of a variety of pearlite, a light gray rock of pearly lustre from the Montezuma Range in the Nevada Basin, as figured by Zirkel; in this, trichite clusters, besides being very numerous, are arranged in lines or planes, and some of the trichites are powdered with pellucid grains, or *globulites*, which are incipient crystals. Zirkel represents another kind in which the radiating trichites are each a string of globulites. Fig. 6 represents a pitchstone from

4.

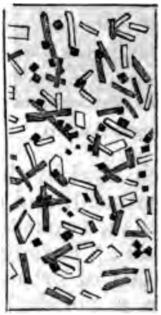
Trichites in obsidian.

5.



Trichites and Fluidal texture in Pearlite.

6.



Microlites in a Pitchstone from Weisselberg.

Weisselberg (from Rosenbusch), in which the microlites are distinctly crystalline in form, and some give evidence that they are feldspar crystals, others that they are augite and magnetite, and indicate that the rock is intermediate between a glass and a doleryte. Thus there is a passage to ordinary stone. Trap or doleryte has been used for making bottle-glass ; and attempts have been made to manufacture glass directly from a variety of granite containing little quartz.

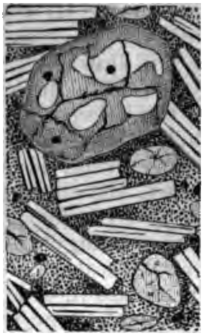
Eruptive rocks, that have come up through fissures, often have glassy particles among the stony in the part near the walls of the fissure when not so through the interior of the mass; and many such rocks, covering large areas, have glassy grains among the stony grains, or a glassy *magma*, because the cooling generally was not slow enough for complete lapidification ; or they have an undefined base, when examined in thin slices, which the microscope does not resolve into crystalline grains. Such portions of a rock are described as *unindividualized.* An unindividualized base exists in the basalt of Truckee Valley, the character of a slice from which, highly magnified, is given in fig. 7, from Zirkel; feldspar crystals, of their usual rectangular forms (part of them sanidin), one of the largish crystals of chrysolite, and smaller irregularly-shaped augites, are imbedded in a base which consists of a glass-like substance ; and in this material there are extremely small globulite grains which are globules of devitrified glass or incipient crystals. The glassy unindividualized base occupies the spaces among the crystalline portions.

These differences in crystalline texture are of small importance compared with differences in mineral and chemical composition. They are results of accidents, and, at the best, lead only to a distinction of varieties among kinds of rocks. The presence of a little glass, or of disseminated large crystals in a porphyritic way, does not make the rock essentially different in kind. If, however, the glassy nature is manifest in the external appearance of the mass, it is convenient to call the rock by a separate name.

Porphyritic rocks are sometimes named as if *porphyry* was a distinct *kind* of rock, or as if the porphyritic section of a kind of rock merited special prominence. But, as recognized beyond, "felsyte-porphyry " is *porphyritic felsyte ;* "doryte-porphyry" is *porphyritic dioryte ;* "diabase-porphyry" is *porphyritic diabase*, or, since diabase cannot be distinguished mineralogically from dolerye, it is *porphyritic doleryte ;* and, in these and other like cases, the being porphyritic is a characteristic of minor value.

Sometimes igneous rocks exhibit under the microscope a *fluidal* texture; that is, the material, when examined in sections, shows wavy lines or bands, which are evidence of a former fluid state, and of movement or flowing when in that state. One variety of this texture is represented in figure 8 (from Zirkel), giving a magnified view of an eruptive rock from the head of Louis Valley, Nevada; and another in figure 5, p. 416. Such rocks have been comprised under the general name of *Rhyolyte* (from the Greek for flowing); but this fluidal texture is presented by rocks of different mineral constitution, and is hence not a proper basis for a *kind* of rock.

7.



Basalt with the base unindividualized.

8.

"Rhyolyte;" Fluidal texture.

2. Anhydrous and Hydrous Crystalline Rocks.—Some eruptive rocks, like doleryte or trap, occur both anhydrous and hydrous. The latter, unlike the former, have the constituent minerals clouded in aspect, however thinly sliced, and often changed in part to a green chlorite—a hydrous mineral—and also sometimes to other hydrous species. Such rocks, moreover, have less lustre, and very frequently they are *amygdaloidal*—that is, contain little cavities that are often almond-shaped (the Latin *amygdalum* meaning

almond), which were made by steam, or vapor of some kind, and are now occupied by minerals. This hydrous or chloritic condition is due to *alteration,* and hence such rocks are properly only *varieties* of the anhydrous instead of being distinct kinds.

The change was probably occasioned by subterranean waters, such as exist as streams among the earth's strata, that were encountered by the liquid rock when on its way up a fissure toward the surface. Hydrostatic pressure prevented the waters from being driven back by the heat, and consequently the vapors were forced to penetrate the igneous mass. In the region of New Haven, Conn.—lying at the south extremity of the Connecticut Valley—the Triassic trap-dikes of the western border of the region, and those outside of the Trias, east or west, in the metamorphic rocks, are *anhydrous,* while those in the middle of the valley and east of this are mostly *hydrous,* showing a difference in exposure to the waters according to the geographical position of the dikes in the valley. Of two parallel ranges of dikes, not half a mile apart, and following concentric curves in their courses (situated twenty miles and more north of New Haven), one (as Percival recognized) is amygdaloidal and hydrous, and the other nearly anhydrous; and the positions of the two kinds, there and elsewhere in the Connecticut Valley, indicate a general relation between the direction of the *present* valleys and that of the subterranean water-channels of *Mesozoic time.*

In very many places coal-like "inspissated bitumen" occurs in the amygdaloidal cavities, which was apparently derived from mineral oil that the action of the heat on the Triassic carbonaceous shales (in some places abounding in fossil fishes) had caused to rise in vapors and penetrate the melted rock. The carbonic acid of the calcite that so often constitutes the amygdules probably came from the action of the heat on limestone encountered at the same time. The deoxidizing action of the carbohydrogen vapors is supposed by J. Lawrence Smith to account for the metallic iron found in some trap or doleryte. The minerals which constitute the amygdules (see p. 297) are largely such as may have been made by the aid of heat and moisture out of the minerals of the rock itself at the points where they occur.

The water that caused the change could not have come from above after the rock was cooled; for the slight surface decomposition the

anhydrous trap now undergoes shows that such waters do not make their way down: and moreover the results could not have been produced without heat. The trap has not been subjected to a metamorphic process; for the Triassic beds are unaltered sandstone. The water was not from the deep-seated source of the erupted trap, for, if so, the dikes would have been all of one kind, instead of being part hydrous and part anhydrous, and the former locally distributed just as subterranean streams of water are likely to be.

In the case of hydrous *metamorphic* rocks, whether containing chlorite, talc, or a hydrous mica, the hydrous minerals were, with rare exceptions, made at the time of the crystallization, and are not a consequence of subsequent alteration.

3. DURABILITY IN ROCKS.—Durability in a rock is due largely (1) to compactness and fineness of texture; and (2) to the absence of any ingredient or mineral that is liable to oxidation. As far within a rock as water and air can gain access, degradation will always be going on, and most rapidly in all crevices along their walls. Alternate melting and freezing will be one means of destruction; direct chemical action of moist air, especially the carbonic acid it contains (p. 108), another; the wedging apart of grains caused by the slightest deposits and oxidations, through infiltrated waters, another. In granite the carbonic acid may take the alkalies out of the feldspar, and so occasion the destruction of the rock.

Hence the practice of testing the durability of a stone for architectural purposes, by putting it into water, and then weighing it, after some days of exposure, to see whether it has gained in weight, is a good one.

Fineness of grain gives further protection against destruction. Alternate heating and cooling in the daily passage of the sun is a destroying agency of great effect, especially on coarse-grained kinds. Rocks have often retained the glacier markings upon them perfectly fresh until now, when they have had a covering of two or three feet of earth; and they have lost such markings after a few years of exposure. This happens often where there is no true decomposition or oxidation of the surface portion of the rock, and must be due largely to the expansion and contraction caused by changing temperature. The finer the grain of the rock the less the chance for this action. There is no more durable rock than a roofing-slate of good quality. Granites, when well polished, will usually resist long all weathering agencies.

The presence of an oxidizable ingredient is a common source of destruction. Pyrite occurs in grains or crystals in almost all kinds of rocks; and it generally oxidizes easily whenever water and air get access to it. Only the firmest crystals resist change, and these not always. A rock containing even a little pyrite can seldom be trusted for architectural purposes. If a limestone contain a few per cent., or even one, of iron or manganese replacing part of the calcium, it has a source of destruction within it. The iron and manganese are sure, after a while, to oxidize; the iron will give rusty stains, and the manganese turn it black, and both will work destruction. A chemical trial is needed to ascertain the fact as to the purity or not of the rock. The presence of iron carbonate (siderite or spathic iron) is the occasion, wherever it exists, of rapid decomposition as far down as moisture and air can reach. This has been one source of the changes producing the great beds of limonite (like those of Western Massachusetts, Salisbury, Connecticut, and other places), in which the rocks are sometimes decomposed to a depth exceeding one hundred feet.

It is a fact to be remembered that a rock which has stood the weather for centuries in its native exposure is a safe material for man's structures; and one that is crumbling is worth little or nothing.

Durability depends much on the climate. In Peru, even sun-burnt bricks will last for centuries.

The resistance to crushing in rocks is ascertained by subjecting cubes of a given size to pressure. In recent experiments by P. Michelot,* Minister of Public Works in France (whose trials numbered over 10,000), the most compact limestones, weighing 2,700 kilograms per cubic meter, were crushed by a weight of 900 kilograms per square centimetre. Compact oölitic limestone of Bourgogne and some other French localities, weighing 2,600 to 2,700 kilograms, bore 700 to 900 kilograms before crushing. Statuary and decorative marbles bore 500 to 700 kilograms.

Of granitic rocks from Brittany, the Cotentin, the Vosges, and the Central Plateau of France, weighing 2,600 to 2,800 kilograms, the best, which admitted of polishing, bore 1,000 to 1,500 kilograms; while the coarser granites of Brest and

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* Exposition Universelle de 1873 à Vienne, p. 401-432; and Annales des Ponts et Chaussées, 1863, 1868, 1870.

Cherbourg and the syenyte of the Vosges bore 700 to 1,000 kilograms; and other coarse granites, in which the large crystals of feldspar were in part decomposed, bore only 400 to 600 kilograms. The green porphyry of Ternuay (Haute Saône), bore 1,360 kilograms; the basalt of Estelle (Puy de Dome), 1,880 kilograms.

In trials by Gen. Gilmore, trap of New Jersey required to crush it 20,750 to 24,040 lbs. a square inch (about 6 c. m. sq.); granite of Westerly, R. I., 17,750; id. of Richmond, Va., 21,250; syenyte of Quincy, 17,750; marble of Tuckahoe, N. Y., 12,950; id. of Dorset, Vt., 7,612; limestone of Joliet, Ill., 11,250; sandstone of Belleville, N. J., 10,250; id. of Portland, Ct., 6,950; id. of Berea, O., 8,300; id. of Amherst, O., 6,650; id. of Medina, N. Y., 17,250; id. of Dorchester, N. B., 9,150.

When absorbent rocks are thoroughly wet the weight required to crush them is greatly reduced. To crush wet chalk, according to trials by Delesse, required only one-third what it did when stove-dried; and for the limestone, "calcaire grossier," of Vitry and other localities, mostly one-third to one-half. Tournaire and Michelot found, for the chalk of the Paris basin, the pressure required when wet two-ninths of that required when the rock had been dried at a temperature considerably above 212° F.

Use of the Microscope in the Study of Rocks. The study of thin, transparent slices of rocks by the microscope is of interest whether the crystalline rock be coarse or fine in texture; but it is particularly important when of the latter kind. There is no rock so opaque that it cannot be made transparent, or at least translucent, in thin slices. Such slices are examined by means of a polariscope-microscope. The increased use of the microscope in the investigation of rocks has led to the introduction, by way of distinction in methods of study, of the word *macroscopic.* An investigation may be carried on *macroscopically*, that is, without the use of a microscope, excepting a pocket lens; or *microscopically*, that is, by the study of thin slices through the aid of the microscope and polariscope.

The more important points ascertained by microscopic methods, as regards the mineral constitution of a rock, are the following:

1. The presence or not of quartz; of a feldspar; of a chlorite.

2. The distinction of a triclinic feldspar from orthoclase, the former showing in sections, cut in any direction excepting one, commonly several parallel spectrum bands, due to multiple twinning in the crystal, while orthoclase shows no bands of the kind, or at the most but two.

3. The presence or not of hornblende; this mineral having often cleavage lines meeting at angles of 124°, and being *dichroic.*

4. The presence or not of pyroxene; this mineral often showing cleavage lines meeting at angles of 87° (nearly a right angle), and being *not* dichroic, and usually distinguished in this way from hornblende.

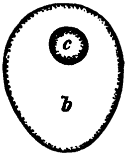
5. The presence or not of mica, its cleavage lines and dichroism affording distinctive characters.

6. The presence or not of chrysolite; of magnetite, its form being often octahedral, and single or grouped; of points or portions having the nature of glass, and therefore not polarizing light; of fluidal lines; of liquid carbonic acid, and of various other *inclusions.* Fig. 9 shows a common form of the grouping of microscopic magnetite crystals in an eruptive rock. Fig. 10 represents a cavity in quartz nearly filled with a liquid, *b*—the small bubble, *c*, showing the part not occupied by it. When the liquid is carbonic acid the air-bubble disappears on raising the temperature to 86°–95° F. Carbonic acid requires a pressure, at 32° F., of 38½ atmospheres to retain it in the liquid state; and hence occurs liquid only in quartz, topaz, and a few other minerals. Fig. 11 (from Zirkel) shows another cavity, containing, besides a liquid, a little cube and microscopic hornblende-like acicular crystals; and the cube is supposed to be common salt in a solution of salt. Hexagonal prisms of apatite (calcium phosphate) are detected by the microscope in

9.

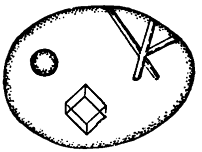
Magnetite in grouped crystals.

10.



Liquid Carbonic Acid.

11.



Cube of Salt in a solution of the same.

almost all kinds of igneous and metamorphic rocks, including trap or doleryte.

For a particular account of the distinguishing characteristics of minerals studied by microscopic methods, reference must be made to treatises on the subject.

IV. KINDS OF ROCKS.

1. Rocks are generally mixtures of two, three, or four prominent mineral constituents, with also others, it may be, of less importance. Each mineral adds a distinctive feature, and might be a reason for a new name. But it is usual with lithologists to base the distinction into *kinds* of rocks on the *two* chief minerals, and make the others *accessory* species and the basis only of *varieties*. This method is prompted by convenience, and also by the fact that the more important characteristics are commonly contained in two of the constituent minerals. It has many exceptions, however, and particularly where a third mineral has special peculiarities and abundance.

2. Difference in kind of rock is naturally based on *difference in chemical or mineral constitution*, and *identity*, accordingly, *on essential identity in this respect*. Consequently when there is no essential difference in chemical or mineral constitution, there is no sufficient reason for a distinction in kind or a difference in name, unless the wide distribution of a particular variety, and the permanence in its characters, make the distinction in name a geological necessity.

In accordance with this statement, the distinctions among crystalline rocks of coarse or fine in texture; of being porphyritic or not; of containing glassy grains among the stony or not; of being foliated or not in crystallization, are of little value compared with the real mineral constitution, and are a fit basis only, at the best, for varieties. But the two rocks of like composition, trachyte and felsyte, retain their characteristics so widely, that geology needs both names, and only demands that their essential identity should be held in mind.

The same kind of rock is in many cases both of metamorphic and eruptive origin; still the difference of origin is not a sufficient basis for a distinction of kind unless there is some marked difference between them, and an extended distribution of each, that makes the case like that of trachyte and felsyte. The author has proposed to use the prefix *meta* for metamorphic kinds when a rock occurs both metamorphic and eruptive; but this is not intended to indicate a distinction in *kind,* but only to abbreviate the qualifying word *metamorphic.*

According to the principles above stated, a rock having oligoclase or albite as its feldspar constituent cannot rightly have the same name with one having either of the *basic* feldspars, labradorite or anorthite, as an essential part, although these feldspars are all embraced under the deceptive title of *plagioclase* (p. 275). Between anorthite and oligoclase there is a difference of 20 per cent. in the silica, and the former is simply a *lime* feldspar; and the contrast is large also between labradorite and oligoclase. Again, for a like reason, as already explained (p. 411), a mica-bearing rock containing little or no hornblende cannot properly be classed with hornblendic rocks.

3. It has been supposed that pre-Tertiary crystalline rocks differed so decisively from the Tertiary and more recent, that those of the two series should not bear the same name. But geology knows nothing of any epoch of sudden transition in the mineral nature of eruptive rocks at the commencement of the Tertiary era; on the contrary, it shows that the kinds made before and after this epoch are alike in mineral constitution, and differ not always even in texture, but only in the greater prevalence after the Tertiary of volcanic or subaërial ejected masses, and therefore of rocks of the texture this involves. The distinction of doleryte from diabase, with others similar, is of this *chronological* kind. Rocks, like other objects in science, should evidently be named from what they are, and not from the age in which they may have been made.

4. Since quartz is the most abundant of all the minerals of the globe, it is the least characteristic of the ingredients of compound rocks. Recent lithologists have made it, in several cases, distinguish only a section under a *kind* of rock. Thus, there are *dioryte* and *quartz-dioryte, felsyte* and *quartz-felsyte, trachyte* and *quartz-trachyte.* On the same principle there are *syenyte* and *quartz-syenyte,* as adopted beyond.

5. The division of crystalline rocks into *acidic* and *basic* rocks is explained on p. 274. The acidic afford on analysis

55 per cent. or more of silica, and the basic usually less than 52.

6. The feldspars are divided, according to their bases, into (1) *potash-feldspars,* including orthoclase and microcline; and (2) those which may be designated *soda-lime-feldspars,* namely the species albite, oligoclase, andesite, labradorite, and anorthite, which yield either soda, or lime, or both, on analysis. The term *plagioclase* has been used for the latter; but it is no longer applicable since microcline is plagioclase. Under the heading *potash-feldspars,* as used beyond, leucite also is included; and under that of *soda-lime-feldspars,* nephelite and sodalite, and also the minerals of the saussurite group.

The kinds of rocks are described under the heads of—

1. FRAGMENTAL ROCKS, EXCLUSIVE OF LIMESTONES.
2. LIMESTONES, OR CALCAREOUS ROCKS.
3. CRYSTALLINE ROCKS, EXCLUSIVE OF LIMESTONES.

No strongly defined limit exists between the fragmental and crystalline rocks. But still they are for the most part widely diverse in character and aspect.

In the names of rocks, the termination *ite* is here changed to *yte,* as done in the author's "System of Mineralogy" (1868), in order to distinguish them from the names of minerals. Granite is excepted.

I. Fragmental Rocks, exclusive of Limestones.

1. Conglomerate.—A rock made up of pebbles or of coarse angular fragments of rocks of any kind. (*a*) If the pebbles are rounded, the conglomerate is a *pudding-stone;* (*b*) if angular, a *breccia.*

Conglomerates are named according to their constituents, *siliceous* or *quartzose, granitic, calcareous, porphyritic, pumiceous,* etc.

2. Grit.—A hard, gritty rock, consisting of coarse sand, or sand and small pebbles, called also *millstone grit,* because used sometimes for millstones.

3. Sandstone.—A rock made from sand: a consolidated sand-bed.

VARIETIES.—a. *Siliceous* or *Quartzose;* consisting chiefly of quartz. b. *Granitic;* made of granitic material or comminuted granite. c. *Micaceous;* containing much mica. d. *Argillaceous;* containing much clay with the sand. e. *Gritty;* hard and containing small quartz pebbles. f. *Ferruginous;* containing iron oxide and having its red color. g. *Concretionary;* made up of concretions. h. *Laminated;* made up of thin layers or laminæ, or breaking into thin slabs, a characteristic most prominent in argillaceous sandstones. i. *Friable;* crumbling in the fingers. j. *Fossiliferous;* containing fossils.

The paving stone extensively used in New York and the neighboring States is a *laminated* sandstone, of the upper part of the Hamilton group in geology, quarried just south of Kingston, and at many other places on the west side of the Hudson River. The rock is remarkable for its very even lamination. In Western New York and in Ohio, the Devonian sandstones, above the Hamilton group, together with the Waverly group, afford a similar flag-stone. The "brown-stone" used much in New York and elsewhere for buildings, is a dark-red sandstone from the Triassic formation, and is quarried at Portland, Conn., on the Connecticut River, opposite Middletown. A lighter-colored "brown-stone" or "*free-stone,*" of the same age, also much used for buildings, comes from Newark, Belleville, Little Falls, and other points in Central New Jersey. The handsome sandstone of light olive-green tint, much employed in architecture, is from the Lower Carboniferous group in New Brunswick. The soft white sandstone, in much esteem among architects because so easily cut and carved, comes from Ohio quarries, in beds of the Carboniferous; it is mostly from a bed about sixty feet thick, called the "Berea grit," and is obtained at Berea and Independence in Cuyahoga County, and Amherst in Lorain County, and elsewhere.

Pyrite is often present in sandstones used for building, and has defaced, and is destroying, many a beautiful structure by its oxidation, and the consequent decay of the rock.

Sandstones absorb moisture most easily in the direction of the bedding or grain, if there is any distinct bedding; and hence the blocks, when used for a building or wall, should be placed with the bedding horizontal. It is, further, the position in which the stone will stand the greatest pressure.

Grindstones are made from an even-grained, rather friable sandstone, and are of different degrees of fineness, according to the work to be done by them.

Hard siliceous sandstones and conglomerates, occurring in regions of metamorphic rocks, are called "granular quartz," and *quartzyte* (p.435).

4. Sand-rock.—A rock made of sand, especially when not of siliceous material. A *calcareous* sand-rock is made of calcareous sand; it may be pulverized corals or shells, such as forms and constitutes the beaches on shores off which living corals and shells are abundant.

The beach sands become cemented below high-water mark into a calcareous sand-rock, which consists of layers having the pitch of the surface of the beach. They are often coarse, calcareous conglomerates.

5. Shale.—A soft, fragile, argillaceous rock, having an uneven slaty structure. Shales are of gray, brown, black, dull-greenish, purplish, reddish and other shades.

VARIETIES.—a. *Bituminous shale*, or *Carbonaceous shale* (*Brandschiefer* of the Germans), impregnated with coaly material and yielding mineral oil or related bituminous matters when heated. b. *Alum shale;* impregnated with alum or pyrites, usually a crumbling rock. The alum proceeds from the alteration of pyrite or the allied pyrrhotite (p. 174).

6. **Argillyte,** *or Phyllyte.*—An argillaceous slaty rock, like shale, but differing in breaking usually into thin and even slates or slabs. Roofing and writing slates are examples. It is sometimes thick-laminated. Unlike shale, it occurs in regions of metamorphic rocks, and often graduates into hydromica, chloritic, and mica schists, and also, on the other hand, into shale. Often called *Clay-slate.*

VARIETIES.—a. *Bluish-black.* b. *Tile-red.* c. *Purplish.* d. *Grayish.* e. *Greenish;* f. *Ferruginous.* g. *Pyritiferous.* h. *Thick-laminated;* affording thick slabs, instead of slates. i. *Thick-bedded;* a massive rock, affording thick blocks or masses. j. *Staurolitic.* k. *Ottrelitic.*

Extensive quarries of slate exist in Vermont at Waterford, Thetford, and Guilford, in the eastern slate range of the State; in Northfield in the central range, and in Castleton and elsewhere in the western range, the last of Lower Silurian age if not the others. There are excellent quarries also in Maine and Pennsylvania. The rock furnishes also thick slabs for various economical purposes. A trial as to water absorption, and a close examination as to the presence of pyrite, is required before deciding that a slate rock is fit for use, however even its fissile structure. Kinds with a glossy surface are most likely to be impervious to moisture.

7. **Tufa.**—A sand-rock or conglomerate made from comminuted volcanic or other igneous rocks, more or less altered. Usually of a yellowish-brown, gray, or brown color, sometimes red.

VARIETIES.—a. *Dolerytic* or *basaltic;* tufa made from those igneous rocks that contain iron-bearing minerals, such as doleryte (trap), basalt, and the heavier lavas; it is usually yellowish-brown or brown in color, sometimes red; and often consists in part of palagonite (p. 312). b. *Trachytic;* made of the feldspathic igneous rock, trachyte, of an ash-gray color, or of other light shades. c. *Pumiceous;* made of fragments of pumice. *Pozzuolana* is a light-colored tufa, found in Italy. near Rome, and elsewhere, and used for making hydraulic cement, *Wacke* is an earthy brownish rock, resembling an earthy trap or doleryte, usually made up of trappean or dolerytic material, compacted into a rock that is rather soft.

8. **Sand. Gravel.**—*Sand* is comminuted rock-material; but common sand is usually comminuted quartz, or quartz and feldspar, while *gravel* is the same mixed with pebbles and stones. Sand often contains grains of magnetite, or

of garnet, or of other hard minerals existing in the rocks of the region. Occasionally magnetite or garnet is the chief constituent.

Volcanic sand, or *Peperino,* is sand of volcanic origin, either the "*cinders*" or "*ashes*" (comminuted lava), formed by the process of ejection, or lava rocks otherwise comminuted.

9. Green Sand.—An olive-green sand-rock, friable, or not compacted, consisting largely of glauconite. See, for description and analysis, p. 307.

10. Clay.—Soft, impalpable, more or less plastic material, chiefly aluminous in composition, white, gray, yellow, red to brown in color, and sometimes black. It has been made chiefly from the feldspars, by decomposition. See Kaolinite.

VARIETIES. — a. *Kaolin,* purest unctuous clay. b. *Potter's clay,* plastic, free from iron; mostly unctuous; usually containing some free silica. *Pipe-clay* is similar. c. *Fire-brick clay,* the same; but it may contain some sand without injury. d. *Ferruginous,* ordinary *brick clay,* containing iron in the state of oxide or carbonate, and consequently burning red, as in making red brick. e. *Containing iron in the state of silicate,* and then failing to turn red on being burnt, as the clay of which the Milwaukee brick are made. f. *Alkaline* and *Vitrifiable,* containing 2·5 to 5 per cent. of potash, or potash and soda, owing to the presence of undecomposed feldspar, and then not refractory enough for pottery or fire-brick. g. *Marly,* containing some carbonate of calcium. h. *Weak clay,* containing too much sand for brick-making. i. *Alum-bearing,* containing aluminous sulphates, owing to the decomposition of iron sulphides present, and hence used for making alum.

The *red pipestone* of the North American Indians is an indurated clayey rock from the Coteau de Prairies; it has been named *Catlinite;* and the *gray* is in part compact argillyte.

11. Alluvium. Silt. Till.—*Alluvium* is the earthy deposit made by running streams or lakes, especially during times of flood. It constitutes the flats either side, and is usually in thin layers, varying in fineness or coarseness, being the result of successive depositions.

Silt is the same material deposited in bays and harbors, where it forms the muddy bottoms and shores.

Læss is a fine earthy deposit, following the courses of valleys or streams, like alluvium, but without division into thin layers. Occurs in elevated plains, along the broad parts of large valleys, as the Mississippi, Rhine, Danube.

Till is the unstratified sand, gravel, and stones, derived from glaciers.

Detritus (from the Latin for *worn*) is a general term applied to earth, sand, alluvium, silt, gravel, because the material is derived, to a great extent, from the *wear* of rocks through decomposing agencies, mutual attrition in running water, and other methods.

Soil is earthy material [illegible]

varieties depending on color are very numerous, and many of them, when pure and compact, are polished and used for marble. The gray and black colors are due commonly to carbonaceous material, for they burn white ; but the yellow, red, and some other kinds to the presence of iron-oxide. There are also : a. *Fossiliferous* or *shell limestone*. b. *Coral* or *Madreporic limestone*. c. *Encrinital* or *Crinoidal limestone ;* containing crinoidal remains in the form mostly of small disks. d. *Nummulitic ;* containing the disk-shaped fossils called Nummulites. e. *Oölitic* limestone ; a limestone having an oölitic texture. f. *Bird's - eye* limestone ; having small whitish crystalline points scattered through it, a rock of Western

New York, of the Trenton period in geology. g. *Conglomerate* limestones.

The *black* marble of the United States comes mostly from Shoreham, Vermont, and other places in that State, near Lake Champlain, and from near Plattsburg and Glenn's Falls, N. Y.; also from Isle La Motte. A *pudding-stone* marble, of various dull shades of color, occurs on the banks of the Potomac, in Maryland, 50 or 60 miles above Washington; it is used for columns in the interior of the Capitol at Washington.

The *Portor* is a Genoese marble very highly esteemed; it is deep black, with veinings of yellow; the most beautiful comes from Porto-Venese. The *Nero-antico* marble of the Italians is an ancient deep black marble; the *paragone* is a modern one, of a fine black color, from Bergamo; and *panno di morte* is another black marble with a few white fossil shells.

A beautiful marble from Sienna, *brocatello di Siena*, has a yellow color, with large irregular spots and veins of bluish-red or purplish. The *mandelato* of the Italians is a light red marble, with yellowish-white spots. The Madreporic marble is the *Pietra stellaria* of the Italians.

Fire-marble, or *lumachelle*, is a dark brown shell marble, having brilliant fire-like or chatoyant reflections from within.

Ruin marble is a yellowish marble, with brownish shadings or lines arranged so as to represent castles, towers, or cities in ruins. These markings proceed from infiltrated iron. It is an indurated calcareous marl, and does not occur in large slabs.

Hydraulic limestone is a compact kind containing some clay, and affording a quicklime the cement from which will set under water. An analysis of a kind from Rondout, N. Y., afforded Carbonic acid 34·20, lime 25·50, magnesia 12·35, silica 15·37, alumina 9·13, iron sesquioxide 2·25. In making ordinary mortar, quartz sand is mixed with pure quicklime and water, and the chemical combination is mainly that between the water and lime, together with subsequently an absorption of carbonic acid. With "hydraulic cement," silica and alumina (that of the clay) are disseminated through the lime, and hence these ingredients enter into chemical union with the lime and water, and make a much firmer cement, and one which "sets" under water.

Oil-bearing limestones occasionally occur. A kind used for building in Chicago, of the Niagara period, becomes spotted or streaked with blackish mineral oil, after a few years' exposure to the weather.

Some of the pyramids of Egypt, including the largest, the pyramid of Cheops, is made of nummulitic limestone; and this is the building material of Aleppo, the range of mountains between Aleppo and Antioch being composed largely of this cream-colored rock.

A soft Tertiary limestone occurring in the vicinity of Paris has afforded a vast amount of rock, of an agreeable pale yellowish color, for fine buildings in Paris; and a similar rock has long been used in Marseilles, Montpellier, Bordeaux, Brussels, and other places in Western Europe.

Most limestones have been made out of comminuted shells, corals, and other like material; and when of dark colors or black, it is usually owing to some carbonaceous matters present derived from the decomposition of the plants or animals of the waters in which they were formed.

When burnt, limestone (CaO_2C) becomes *quicklime* (CaO), through loss of carbonic acid (CO_2); and, at the same time, all carbonaceous materials are burnt out, and the color, when it is owing solely to these, becomes white.

2. **Magnesian Limestone. Dolomyte.**—Carbonate of calcium and magnesium, but not distinguishable in color or texture from ordinary limestone. The amount of magnesium carbonate afforded by analyses varies from a few per cent. to that of true dolomite (p. 55).

Much of the common limestone of the United States is magnesian. That of St. Croix, Wisconsin, the "Lower Magnesian," afforded Owen 42·43 per cent. of magnesium carbonate.

In some limestones the fossils are magnesian, while the rock is common limestone. Thus, an *Orthoceras*, in the Trenton limestone of Bytown, Canada (which is not magnesian), afforded T. S. Hunt, Calcium carbonate 56·00, magnesium carbonate 37·80, iron carbonate 5·95 =99·75. The pale-yellow veins in the Italian black marble, called "Egyptian marble," and "portor" (see above), are dolomite, according to Hunt; and a limestone at Dudswell, Canada, is similar.

3. **Chalk.**—A white, earthy limestone, easily leaving a trace on a board. Composition the same as that of ordinary limestone.

4. **Marl.**—A clayey or earthy deposit containing a large proportion of calcium carbonate—sometimes 40 to 50 per cent. If the marl consists largely of shells or fragments of shells, it is called *Shell-marl.*

Marl is used as a fertilizer; and other beds of clay or sand that can be so used are often in a popular way called *marl.* The "Green sand" of New Jersey (p. 429) is of this kind.

5. **Travertine.**—A massive limestone, formed by deposition from calcareous springs or streams. The rock abounds on the river Anio, near Tivoli, and St. Peter's at Rome is constructed of it. The name is a corruption of *Tiburtine.* It occurs in the Yellowstone Park, along Gardiner's River.

6. **Stalagmite.**—See page 216.

2. CRYSTALLINE LIMESTONE.

1. **Granular** or **Crystalline Limestone** (Marble).—Limestone having a crystalline-granular texture, white to gray color, but often of reddish and other tints from impurities. It is a *metamorphic* rock; it was originally common limestone; it became crystalline under the action of more or less heat; in

the process all the fossils present were obliterated, except in some cases of partial metamorphism. Its impurities are often *mica* or *talc, tremolite, white* or *gray pyroxene* or *scapolite;* sometimes *serpentine,* through combination with which it passes into ophiolyte (p. 453); occasionally *chondrodite, apatite, corundum.*

VARIETIES.—a. *Statuary marble;* pure white and fine grained. b. *Decorative* and *Architectural marble;* coarse or fine, white, and mottled of various colors, and, when good, free not only from iron in the form of pyrite, but also from iron or manganese in the state of carbonate with the calcium, and also from all accessory minerals, even those not liable to alteration, and especially those of greater hardness than the marble which would interfere with the polishing. c. *Verd-antique,* or *Ophiolyte.* d. *Micaceous.* e. *Tremolitic;* contains bladed crystallizations of the white variety of hornblende called tremolite. f. *Graphitic;* contains graphite in iron-gray scales disseminated through it. g. *Chloritic;* contains disseminated scales of chlorite. h. *Chondroditic;* contains disseminated chondrodite in large or small yellow to brown grains.

White and grayish-white marble is abundant in Western New England, and Southeastern New York (Westchester County). The texture is less coarsely crystalline in Vermont than in Massachusetts, the crystallization of the limestone as well as of the associated schists increasing in coarseness from the north to the south, or rather south-southwest, which is the trend of the limestone belt. Fine marbles are quarried in Dorset, West Rutland, Pittsford, and other places in Vermont, and the best of statuary marble occurs abundantly in Pittsford. The whitest marble of Rutland is not as firm as that mottled with gray, owing apparently to the fact that it was made white by the heat that crystallized it burning out any carbonaceous material; while at Pittsford, 16 miles to the north of Rutland, it is very firm, and is white, probably, because it was made with less heat from a whiter limestone. In Vermont, the best quarries occur where the strata stand at a high angle: the layers in such regions were subjected to great pressure in the upturning that gave them this position, and this pressure has soldered many layers together in one that are separate where the pressure was less; consequently blocks as large as an ordinary house might be obtained at some of the quarries. Good marble is also quarried in Pennsylvania, Maryland, and Tennessee. One of the most beautiful marbles from deposits of crystalline limestone in the United States, is the mottled reddish-brown from East Tennessee, and mainly from Knox and Hawkins counties. Another handsome marble is the mottled red of Burlington, Vt., from the semi-crystalline Winooski limestone; and a still finer the deeper red (or cherry-red), mottled and veined with white, of Swanton, Vt., from the same limestone on the northern borders of the State.

The Carrara marble of Italy, the Parian, of the island of Paros (the birthplace of Phidias and Praxiteles), and the Pentelican, from quarries near Athens, Greece, are examples of crystalline limestone. The Carrara marble varies in quality from coarse to true statuary marble, and the best comes from Monte Crestola, and Monte Sagro. Out of the 500 quarries only 20 furnish stone for the sculptor. The amount of marble taken out from the quarries in 1876, was 120,000 tons, valued at $2,400,000 ; and of this 40,000 tons came to the United States. The *Cipolin* marbles of Italy are white, or nearly so, with shadings or zones of green talc.

2. **Dolomyte.**—Not distinguishable by the eye from granular limestone.

Part of the marbles above referred to are dolomyte. This is the case with that of Westchester County, N Y., that of Canaan, Connecticut, and of Lee and Stockbridge, Massachusetts.

II. Crystalline Rocks, exclusive of Limestones.

The crystalline rocks may be distributed according to their composition into the following series or groups. Each, excepting the first, embraces both metamorphic and eruptive rocks.

1. **Siliceous rocks.** The kinds consisting mainly of quartz or opal are here included. The first of those mentioned, page 435, is intermediate between the fragmental and metamorphic-crystalline rocks. The opal material is a chemical deposit. The chert of sedimentary formations is believed to be mainly tripolite consolidated through the solution of a part of its material by the permeating waters and its subsequent desposition—tripolite or diatom beds being made chiefly of opal-silica which is readily soluble in waters slightly alkaline.

2. **The Mica and Potash-Feldspar series.** These are eminently alkali-yielding rocks, both the mica, whether muscovite, biotite, or lepidomelane, and the feldspar, whether orthoclase or microcline, affording on analysis, as explained on page 411, much potash, and the feldspars often also some soda. The soda feldspar, albite or oligoclase, is a common accessory ingredient. The series shades off into a rock that is chiefly feldspar, and another that is chiefly mica ; and in these two extremes the amount of potash yielded is about the same. Moreover, as leucite is essentially a potash-feldspar in ratio and composition (see page 411), rocks, consisting chiefly of leucite, without pyroxene or hornblende, belong with this series. Muscovite and biotite commonly occur together, the formation of biotite having been determined by the presence of some iron oxide in the original material from which it was made. The mica is sometimes a hydrous species (page 313).

3. The Mica and Soda-lime-Feldspar series. These granitoid rocks are equally alkali-yielding with those of the true granite group, but the alkali is mainly soda. The nephelite (elæolite) rocks not hornblendic are here included, although they contain in general some microline or orthoclase.

4. The Hornblende and Potash-Feldspar series, or the **Syenyte group.** In this series, the mica of the granite series is replaced by the non-alkaline mineral, hornblende. Transitions between the granite and syenyte rocks are common—a bed that is true mica schist often becoming hornblendic; the same specimen may have mica and hornblende crystals together, or parallel mica and hornblende layers, and then not far beyond the schist may be a purely hornblende rock; and so there are similar transitions in other parts of the two series. This transition in a stratum of mica schist, a metamorphic rock, indicates merely that the mud-bed or sedimentary stratum, out of which the mica schist was made, had a diminished proportion of alkali in some parts, and, in still others, a complete absence of alkali—which is just such a variation as might be looked for in oceanic sediments, as they spread over a wide region. The hornblende may be replaced by epidote, another iron-bearing mineral.

5. The Hornblende and Soda-lime-Feldspar series. The soda-lime-feldspars, in this series, may be either of the triclinic species, from albite to anorthite.

6. The Pyroxene and Soda-lime-Feldspar series. The soda-lime-feldspars are the same as in the preceding. Quartz is very rarely present, except in traces. Potash replaces soda in amphigenyte.

7. Pyroxene, Garnet, Epidote and Chrysolite rocks, containing little or no Feldspar.

8. Hydrous Magnesian and Aluminous rocks.

9. Iron Ore rocks

1. SILICEOUS ROCKS.

1. Quartzyte, Granular Quartz.—A siliceous sandstone, usually very firm, occurring in regions of metamorphic rocks. It does not differ essentially from the harder siliceous sandstones of other regions. Conglomerate beds are sometimes included.

VARIETIES.—a. *Massive.* b. *Schistose.* c. *Calcareous;* sometimes contains disseminated calcite which, where the rock is exposed to weathering, is removed and leaves the rock loose in texture, or cellular. d. *Micaceous.* e. *Hydromicaceous;* it graduating at times into hydromica or mica slate. f. *Feldspathic*, sometimes *porphyritic* (the rock *Arkose*), or like *granulite* in its disseminated feldspar ; a coarsely feldspathic variety occurs north of Lenox, Mass., and when it loses its feldspar, it becomes cellular, like buhrstone ; at other places, as in Cheshire, Savoy, and eastern Washington, Mass., the feldspar of a feebly-consolidated quartzyte has been leached out by the filtrating waters, and the rock reduced thereby to *sand*, excellent for glass-making, while in some localities the feldspar so removed has been made into valuable beds of white kaolin, as in Brandon, Vermont, East Sheffield, Mass., and elsewhere. g. *Gneissoid;* containing some mica and feldspar in layers, and so graduating toward gneiss. h. *Andalusitic;* containing andalusite, as in Mt. Kearsarge (Hitchcock). i. *Tourmalinic;* containing tourmaline. The vicinity of the great crystalline limestone formation of the Green Mountain region, in Western New England (in Vermont to the west of the principal ridge of the Green Mountains), includes strata of quartzyte of great thickness, and high summits in Bennington, and to the north, and also south, consist of it. In several places the quartzyte strata graduate into, and also alternate with, hydromica or mica slates, and in Massachusetts and Connecticut, with gneiss. Between Bernardston, Mass., and Vernon, Vt., quartzyte occurs in large beds, and also graduates into gneiss and hornblendic rocks. Quartzyte exists also in the central part of the Southern New Hampshire, in the Archæan area of Wisconsin, and in the Rocky Mountain region. j. *Novaculitic-quartzyte*, or *Novaculyte* (*Whetstone*). Novaculyte is only in part an extremely fine-grained siliceous rock. Of this nature is the variety from Whetstone or Hot Spring Ridge, in Arkansas. This ridge, 250 feet in height above the Hot Spring Valley, is made up of the beautiful rock, "equal," says D. D. Owen, "in whiteness, closeness of texture, and subdued waxy lustre, to the most compact forms and whitest varieties of Carrara marble. Yet it belongs to the age of the millstone grit." Dr. Owen supposed it to have received its impalpable fineness through the action of the hot waters on sandstone. An analysis of the rock afforded him (Second Rep. Geol. Arkansas, 1860, p. 24), Silica 98·0, alumina 0·8, potash 0·6, soda 0·5, moisture, with traces of lime, magnesia and fluorine 0·1 = 100. He states that along the southern flank of the ridge there are over forty hot springs, having a temperature of 100° F. to 148° F. Solid masses from the fine rock have been got out weighing about 1,200 lbs.; the coarser varieties are made into stones for bench tools.

Beds of quartzyte have been made, like those of sandstone, out of the quartz grains of older rocks, no evidence, chemical or geological, favoring the view that they could be, or have been, produced by chemical deposition. Some quartzytes and sandstones have had part of the grains *converted into more or less perfect quartz crystals*, from the deposition about them of silica in the process of consolidation—the little heat required for making the siliceous waters coming from the earth's interior, as a consequence of thick accumulations of strata above, or from the friction of upturning, or from warm springs.

2. Itacolumyte.—Schistose, consisting of quartz grains with some hydrous mica ; on account of the mica in the lamination, it is sometimes flexible, and is called *flexible sandstone.*

Occurs in the gold regions of North Carolina and Brazil, and diamonds are supposed to be sometimes connected as to origin with this rock.

3. **Siliceous Slate.**—Schistose, flinty, not distinctly granular in texture. Sometimes passes into mica slate or schist.

4. **Chert.**—An impure flint or hornstone occurring in beds or nodules in some stratified rocks. It often resembles *felsyte*, but is infusible. Colors various. Sometimes oölitic. Kinds containing iron oxide graduate into jasper and clay ironstone; and others, occurring as layers or nodules in limestone are whitish, owing to the limestone material they contain. Chert sometimes contains cavities which are lined with chalcedony or agate, or with quartz crystals.

5. **Jasper rock.**—A flinty siliceous rock, of dull red, yellow, or green color, or some other dark shade, breaking with a smooth surface like flint. It consists of quartz, with more or less clay and iron oxide. The red contains the oxide in an anhydrous state, the yellow in a hydrous; on heating the latter it turns red.

6. **Buhrstone.**—A cellular siliceous rock, flinty in texture. Found mostly in connection with Tertiary rocks, and formed apparently from the action of siliceous solutions on preëxisting fossiliferous beds, the solutions removing the fossils and leaving cavities.

Buhrstone is the material preferred for millstones. The buhrstone of the vicinity of Paris, France, has long been largely exported for this purpose. Good buhrstone is obtained also from the Tertiary in Greenville District, South Carolina, 100 miles up the Savannah River.

7. **Fioryte.** (*Siliceous Sinter, Pearl Sinter, Geyserite.*)—Opal-silica, in compact, porous, or concretionary forms, often pearly in lustre; made by deposition from hot siliceous waters, as about geysers (*Geyserite*), or through the decomposition of siliceous minerals, especially about the fumaroles of volcanic regions.

Geyserite is abundant in Yellowstone Park, and about the Iceland geysers; after long exposure it crumbles down and becomes changed to ordinary silica, or quartz.

2. MICA AND POTASH-FELDSPAR SERIES.

1. **Granite.**—Consists of quartz, orthoclase, and mica, and has no appearance of layers in the arrangement of the mica or other ingredients. G.=2·5–2·8. The *quartz* is usually grayish-white or smoky, glassy, and *without any appearance*

of cleavage. The *feldspar* is commonly whitish or flesh-colored, and may be distinguished from the quartz by its cleavage surfaces, which reflect light brilliantly when the specimen is held in the sunlight. The *mica* is usually in small bright scales, either silvery, brownish-black, or black in color, and the point of a knife carefully used will easily split them into thinner scales; the silvery mica is muscovite, but sometimes of the allied hydrous kinds, margarodite or damourite, and the black mica is usually biotite, though occasionally the allied, more iron-bearing, species, lepidomelane. Oligoclase or albite is very often present.

Occurs both metamorphic and eruptive. Metamorphic granite may often be seen graduating into gneiss, or lying in beds alternating with gneiss.

VARIETIES.—There are, A. Muscovite granites; B. Biotite granites; C. Muscovite-and-biotite granites, the last much the most common. The most of the following varieties occur under each except the hornblendic, which is usually a Biotite, or Muscovite-and-Biotite, granite. There is also, D. Hydromica-granite. a. *Common* or *Ordinary granite;* the color is grayish or flesh-colored, according as the feldspar is white or reddish, and dark gray when much black mica is present. Granite varies in texture from *fine* and even, to *coarse;* and sometimes the mica, feldspar, and quartz—especially the two former—are in large crystalline masses. An average granite (mean of 11 analyses of Leinster granite, by Haughton) affords Silica 72·07, alumina 14·81, iron protoxide and sesquioxide 2·52, lime 1·63, magnesia 0·33, potash 5·11, soda 2·79, water 1·09=100·35. b. *Porphyritic granite;* has the orthoclase in defined crystals, and may be (α) small porphyritic, or (β) large porphyritic, and have the base (γ) coarse granular, or (δ) fine, and even subaphanitic. c. *Albitic granite;* contains some albite, which is usually white. d. *Oligoclase granite* (*Miarolite*)*;* contains much oligoclase. e. *Microcline granite;* contains the potash triclinic feldspar, microcline. f. *Hornblendic granite;* contains black or greenish-black hornblende, along with the other constituents of granite. g. *Black micaceous granite;* consists largely of mica, with defined crystals of feldspar (porphyritic), and but little quartz. h. *Iolitic;* containing iolite. i. *Globuliferous granite;* contains concretions which consist of mica, or of feldspar and mica. j. *Gneissoid granite;* a granite in which there are traces of stratification; graduates into gneiss. k. *Pegmatyte,* or *Graphic granite;* consists mainly of orthoclase and quartz, with but little mica; but the quartz is distributed through the feldspar in forms looking like oriental characters.

A porphyritic granite, occurring at the junction of the andalusite mica-argillyte (page 441) of the White Mountain Notch, N. H., with the Mt. Willard granite, on the west side of Mt. Willard, conformable with the bedding of the argillyte, has the argillyte for its base; and in it the orthoclase is in large well-defined crystals, and the quartz in double six-sided pyramids, both easily separable from the matrix; the layer is six to twenty feet thick.

The distinctions as to kinds of rocks between metamorphic and eruptive granites are not yet made out. A porphyritic variety, having the base fine-grained, occurs east of Parkview Peak, in the Rocky Mts., which, according to Hague, is eruptive and related to the trachytes of the region. The granite of New England is for the most part metamorphic or in veins. The following are prominent regions of the granite quarries. In Maine: at Hallowell, a whitish granite, sometimes a little gneissoid; at Rockport, whitish; at Clarke's Island, spotted gray; at Jonesbury, flesh-red; also in the Mt. Desert region. In New Hampshire, at various places, but most prominently near Concord, a fine-grained whitish granite. In Massachusetts at several points, especially in Gloucester at Rockport, a red granite. (The Quincy "granite" is a syenyte.) In Rhode Island, at Westerly, a fine-grained whitish granite. In Connecticut, at Millstone Point near Niantic, and at Groton, near New London, a fine-grained whitish granite; at Stoney Creek, a pale reddish, but liable to large micaceous spots; at Plymouth, on the Naugatuck, a whitish granite, even and fine-grained, more easily worked than the Westerly.

2. Granulyte. (*Leptinyte.*)—Like granite, but containing no mica, or only traces. Metamorphic and eruptive.

VARIETIES.—a. *Common* granulyte; white and usually fine granular, a common rock in Western Connecticut and Westchester Co., New York. b. *Flesh-colored;* usually coarsely crystalline, granular, and flesh-colored; the coarse flesh-colored "granite" of the Eastern or Front Range of the Rocky Mts., in Colorado, sometimes called *Aplite,* is partly of this kind; it contains a little albite or oligoclase with the orthoclase. c. *Garnetiferous.* d. *Hornblendic;* containing a little hornblende—a variety that graduates into syenyte. e. *Magnetitic;* containing disseminated grains of magnetite, a kind common in Archæan regions, in the vicinity of the iron ore beds, occurring in Orange Co., N. Y., and south in New Jersey, and also at Brewster's, Dutchess Co., N. Y., and in Kent and Cornwall, Conn. f. *Graphic* (*Pegmatyte*); like graphic granite, but containing no mica. The coarser granulyte, especially that of veins, is often called pegmatyte when *not* graphic.

3. Gneiss.—Like granite, but with the mica and other ingredients more or less distinctly in layers. Gneiss breaks most readily in the direction of the mica layers, and hence its schistose structure; in consequence of this structure, many kinds may be got out in slabs. It often graduates imperceptibly into granite. Metamorphic.

VARIETIES.—Similar to those under granite. a. *Porphyritic.* b. *Albitic.* c. *Oligoclase-bearing.* d. *Hornblendic.* e. *Micaceous.* f. *Globuliferous.* g. *Epidotic.* h. *Garnetiferous.* i. *Andalusitic;* contains andalusite in disseminated crystals. j. *Cyanitic;* contains cyanite, a variety that has been observed on New York Island, and also in Newtown, Ct., Bellows Falls and elsewhere in N. H. k. *Graphitic;* contains graphite disseminated through it. l. *Quartzose;* the quartz largely in excess. m. *Quartzytic;* consists largely of quartz in grains, being intermediate between quartzyte and gneiss, a variety occurring just northeast of Bernardston, Mass. Fig. 3 on page 415 represents, natural size, a small piece of the porphyritic gneiss of Birmingham, Conn.

Some gneiss is very little schistose, being in thick, heavy beds, granite-like, while other kinds, especially those containing much mica, are thin-bedded, and very schistose; the latter graduate into mica schist. The so-called granite of Monson, Mass., is a granitoid gneiss. Its gneissoid structure facilitates greatly the quarrying.

4. Protogine. Protogine-gneiss.—Coarse to fine granular, granite-like or gneissoid in structure, and mostly the latter; of a grayish-white to greenish-gray color; consists of quartz, white or grayish-white, rarely flesh-red, orthoclase, a dark green mica and often chlorite, with some greenish-white talc, and white oligoclase. Metamorphic.

The dark green mica approaches chlorite, as shown by Delesse, in its very large percentage of iron oxide (Fe_2O_3 21·31, FeO 5·03), but it gave him only 0·90 of water, with 6·05 of potash. Among accessory minerals are hornblende, titanite, garnet, serpentine, magnetite. In an analysis of the protogine as a whole, Delesse obtained Silica 74·25, alumina 11·58, iron oxide 2·41, lime 1·08, water 0·97, leaving 10·01 for potash, soda and magnesia. From the region of Mont Blanc and other parts of the Swiss Alps.

5. Mica Schist.—Consists largely of mica, with usually much quartz, some feldspar, and, on account of the mica, divides easily into slabs, that is, is very schistose. Usually both of the potash micas, muscovite and biotite, are present, and the latter (black mica) is commonly much the most abundant. The colors vary from silvery to black, according to the mica present. Often crumbles easily; and roadsides are sometimes spangled with the mica scales. The disseminated scales or crystals of biotite are sometimes set transversely to the bedding. Metamorphic.

VARIETIES.—a. *Gneissoid;* between mica schist and gneiss, and containing much feldspar, the two rocks shading into one another. b. *Hornblendic.* c. *Garnetiferous.* d. *Staurolitic.* e. *Cyanitic.* f. *Andalusitic.* g. *Fibrolitic;* containing fibrolite. h. *Tourmalinic.* i. *Calcareous;* limestone occurring in it in occasional beds or masses. j. *Graphitic,* or *Plumbaginous;* the graphite being either in scales or impregnating generally the schist. k. *Quartzose;* consisting largely of quartz. l. *Quartzytic;* a quartzyte with more or less mica, rendering it schistose. m. *Specular,* or *Itabyrite;* containing much hematite or specular iron in bright metallic lamellæ or scales. In fine-grained mica schist, the scales of mica are sometimes scarcely visible without a lens.

6. Hydromica Schist.—A thin-schistose rock, consisting either chiefly of hydrous mica, or of this mica with more or less quartz; having the surface nearly smooth, and feeling greasy to the fingers; pearly to faintly glistening in lustre; whitish, grayish, pale greenish in color, and also of darker shades. For analyses of hydrous micas see page 313. Metamorphic.

This rock used to be called *talcose slate*, but, as first shown by Dr. C. Dewey, it contains no talc. It includes *Parophite schist, Damourite slate* and *Sericite slate* (*Glanz-Schiefer* and *Sericit-Schiefer* of the Germans.)

VARIETIES.—a. *Ordinary;* more or less silvery in lustre. b. *Chloritic;* contains chlorite, or is mixed with chlorite slate, and has therefore spots of olive-green color; graduates into chlorite slate. c. *Garnetiferous.* d. *Pyritiferous;* contains pyrite in disseminated grains or crystals. e. *Magnetitic;* contains disseminated magnetite. f. *Quartzytic;* consists largely of quartzyte, or is a quartzyte rendered schistose and partly pearly by the presence of hydrous mica, as is well seen in a ridge northeast of Rutland, Vermont, which consists partly of quartzyte and partly of hydromica schist.

7. **Paragonite Schist.**—Consists largely of the hydrous soda mica called paragonite (p. 314); but in other characters resembles hydromica schist. Metamorphic.

8. **Minette.**—Brown to black, fine-grained, compact, not distinctly schistose; consisting of biotite (according to the description and analysis of Delesse) and orthoclase; contains also a little hornblende. Occurs in beds in the Vosges, France, associated with granite, syenyte, and other crystalline rocks. Sometimes feebly porphyritic and small-concretionary, the concretions consisting mainly of orthoclase. Made eruptive by Delesse, and metamorphic by some later authors. Approaches argillyte in aspect.

9. **Greisen.**—Massive, without schistose structure. A mixture of granular quartz and mica, in scales. The mica may be muscovite, lepidolite, or biotite. It is a granite with the feldspar left out, and occurs in regions of gneiss, granite, or quartzyte, and sometimes graduates into these rocks. Metamorphic.

Occurs in characteristic form at Zinnwald, in the Erzgebirge, where it sometimes contains tin ore as an accessory ingredient, and is frequently penetrated by veins of tin; also in the tin ore regions of Schlackenwald and Cornwall. Occurs in the region of quartzyte, hornblendic rocks and gneiss, of Upper Silurian age, between Bernardston, Mass., and Vernon, Vt., within three miles northeast of the former place, and also near Vernon; but at this place it contains usually a little hornblende, making it a very tough rock, and is intermediate between the quartzyte, hornblendic rock and mica schist of the region.

10. **Mica-Argillyte or Mica-Phyllyte.**—Includes the part of argillyte (p. 428) which has the composition nearly of a hydrous mica, like that of the White Mountain Notch, where

much of it is *andalusitic*. Analysis of this White Mountain rock, by Hawes, afforded Silica 46·01, alumina 30·56, iron sesquioxide 1·44, iron protoxide 6·85, manganese protoxide 0·10, magnesia 1·42, soda 1·12, potash 6·66, titanium dioxide 1·91, water 4·13=100·22. (Compare with analyses of hydrous muscovite, or margarodite.) Metamorphic.

11. Felsyte. Quartz-Felsyte. (*Euryte, Petrosilex.*)—Compact orthoclase, with often some quartz intimately mixed; fine granular to flint-like in fracture; sometimes contains oligoclase. Colors white, grayish-white, red, brownish-red to black. G.=2·6–2·7. Both metamorphic and eruptive.

VARIETIES.—There are two sections, I. Felsyte, and II. Quartz-Felsyte, and under each occur the following varieties. a. *Porphyritic Felsyte*, or *Porphyry*; containing the feldspar in small crystals distributed through the compact base; color red and of other shades; called sometimes *Quartz-porphyry*, when the base is a quartz-felsyte.) b. *Conglomerate felsyte*; containing pebbles, as at Marblehead, Mass., and in the White Mountains. c. *Oligoclase-bearing*; containing this triclinic feldspar intimately blended with the orthoclase. d. *Cellular* or *amygdaloidal*. e. *Elvanyte*; essentially a quartzose felsyte, of gray, bluish-gray to brown and red colors, and often containing disseminated grains or crystals of quartz and feldspar, and some oligoclase; some compact slate-rock has the same composition. Occurs in Cornwall.

The metamorphic and eruptive kinds are not easily distinguished. The former occurs associated with sedimentary strata, and often contains pebbles or other evidence of fragmental origin; while the latter is frequently in dikes, that is, fills the fissures through which it was ejected. Some of the eruptive felsyte has nearly the aspect of trachyte, with which rock it is identical in composition. Much of the red porphyry contains hornblende with the feldspar of the base, and has the constitution of dioryte (p. 447).

12. Porcelanyte. (*Porcelain Jasper.*)—A baked clay, having the fracture of flint, and a gray to red color; it is somewhat fusible before the blowpipe, and thus differs from jasper. Formed by the baking of clay-beds, when they consist largely of feldspar. Such clay-beds are sometimes baked to a distance of thirty or forty rods from a trap dike, and over large surfaces by burning coal beds. Metamorphic.

13. Trachyte. Quartz-Trachyte.—Consists mainly of feldspar, which is partly in glassy crystals, either sanidin or oligoclase; and, owing to the angular forms of the glassy feldspar and the porosity of the rock, the surface of fracture is rough, whence the name from the Greek *trachus*, rough. Sometimes contains disseminated quartz, and is then *quartz-trachyte*. Color ash-gray, greenish-gray, brownish-gray, but sometimes yellowish and reddish. G.=2·5–2·7. Besides the feldspar there are distributed, somewhat sparingly, through the mass, in many kinds, minute needles of hornblende, crystals or scales of biotite, magnetite; sometimes nephelite, haüynite, tridymite. Apatite exists in the rock in microscopic forms, and there is also more or less of the rock in a glassy state. Sometimes contains augite, and has a higher specific gravity. Quartz-trachyte has often nearly the composition of granite in which there is little mica. Eruptive only.

VARIETIES.—The two principal divisions under each, trachyte and quartz-trachyte, are: A. *Sanidin-trachyte,* in which the mass is chiefly sanidin; and B. *Oligoclase-trachyte,* or *Domyte,* in which it is partly oligoclase; but the two graduate into one another. Both occur *porphyritic* with tabular crystals of feldspar; and in the latter (as at the Drachenfels) the tables are sanidin. They graduate into *vesicular* or *scoriaceous trachyte.*

Trachyte, according to Reyer and Suess, occurs in the region of the Euganean Hills of Tertiary, Cretaceous and Jurassic age; and the felsyte of Paleozoic age is often hardly distinguishable from it, while identical with it in composition.

Trachyte and *quartz-trachyte* graduate also into felsyte-like volcanic rocks of like constitution, porphyritic or not so. The latter sometimes shades into rocks of semi-glassy nature called

14. **Pearlstone,** when somewhat pearly in lustre; PITCHSTONE when having a pitch-like lustre; and these into the glassy volcanic material called *Obsidian.* These glassy rocks often contain spherules which are concretions consisting of feldspar with some quartz. *Pumice* is a light, porous, feldspathic scoria, with the pores capillary and parallel. Ordinary obsidian, that consists chiefly of feldspar, and is hence nearly free from iron, belongs here; the rest of it belonging with the augitic igneous rocks.

15. **Leucityte.**—A grayish rock consisting chiefly of leucite in a felsitic state, with disseminated leucite crystals. Occurs at Point of Rocks, Wyoming Territory, according to King and Zirkel. It differs from amphigenyte, in containing no pyroxene, or only traces of it.

3. MICA AND SODA-LIME-FELDSPAR ROCKS.

I. NOT CONTAINING NEPHELITE.

1. **Hemi-dioryte.** (*Mica-dioryte, Soda-granite.*)—A granite-like rock, in which the feldspar is chiefly oligoclase; it contains much biotite, with usually some quartz, and often some hornblende. Occurs at Stony Point, on the Hudson,

and near Cruger's, in the town of Cortland, N. Y., at the latter place often graduating into a granite-like dioryte.

Kersantyte is described by Delesse as consisting of biotite and oligoclase, with some quartz, frequently hornblende in needles, and magnetite ; from the Vosges, the Saxon Erzgebirge, and Nassau. *Kersanton* is a similar rock, containing no hornblende, from near Brest, and from Quimper, in Brittany. Both of these rocks have been called *mica-dioryte.*

Kinzigyte is a compact and schistose granular-crystalline rock, consisting of biotite, oligoclase, and garnet, without quartz, and containing, as accessory, microcline, iolite and fibrolite ; from Kinzig, north part of Black Forest.

II. CONTAINING NEPHELITE.

1. **Miascyte.**—Granitoid to schistose, and consisting of microcline, massive nephelite (elæolite), sodalite, biotite, along with some quartz, and often some zircon, pyrochlore, monazite and other minerals. A related nephelite rock occurs on Pic Island, Lake Superior. Named by G. Rose, from Miask in the Ilmen Mountains, where it has a wide distribution. Metamorphic.

2. **Ditroyte.**—A coarse to fine-grained rock, consisting of microcline, nephelite (elæolite), and sodalite. From Ditro in Eastern Transylvania, where it is associated with syenyte and mica schist and lies between these two rocks.

3. **Phonolyte.** (*Clinkstone.*)—Compact ; of grayish, blue, and other shades of color ; more or less schistose or slaty in structure; tough, and usually clinking under the hammer, like metal, when struck, whence the name. G.=2·4–2·7. Consists of glassy feldspar (orthoclase or oligoclase), with *nephelite* and some hornblende. G. Jenzsch gives, for the composition of the Bohemian phonolyte, Sanidin (glassy orthoclase) 53·55, nephelite 31·76, hornblende 9·34, sphene 3·67, pyrite 0·04=98·36. Under treatment with acids the nephelite is dissolved out. Nosean and haüynite occur in some phonolyte. Eruptive only.

4. HORNBLENDE AND POTASH-FELDSPAR SERIES.

In this series the hornblende is sometimes replaced by epidote, another anhydrous iron-bearing mineral, yielding on analysis little or no alkali ; microcline is often present as well as orthoclase. The species graduate into kinds consisting almost solely of hornblende. Biotite is often present as an accessory mineral.

I. NOT CONTAINING NEPHELITE.

1. Syenyte. Quartz-Syenyte.—A granitoid rock consisting of hornblende and orthoclase, with or without quartz. Oligoclase and biotite are often present. The quartziferous variety, or *quartz-syenyte*, includes the syenyte of the obelisks and pyramids of Egypt. Like that, the rock is often flesh-colored; but whitish and grayish varieties are also common. The Saxon syenyte, without quartz, afforded Silica 59·83, alumina 16·85, iron protoxide 7·01, lime 4·43, magnesia 2·61, potash 6·57, soda 2·44, water 1·29, and G. = 2·75–2·90. Metamorphic and eruptive. Similar varieties occur under both divisions of syenyte.

VARIETIES.—a. *Porphyritic.* b. *Albitic;* containing albite in addition to the constituents of true syenyte. c. *Oligoclase-bearing.* d. *Micaceous;* containing disseminated black mica, which is usually biotite, and sometimes lepidomelane. e. *Garnetiferous.* f. *Epidotic;* containing disseminated epidote. The gray "granite" of Quincy, Massachusetts, south of Boston, extensively quarried for architectural purposes, is a quartz-syenyte, consisting of orthoclase, black to dark green hornblende, and quartz, with some triclinic feldspar. Quartz-syenyte occurs also in the Frankenstein Cliff, five miles south of White Mountain Notch; also in Mount Chocorua, N. H.; in the Archæan of Canada, at Grenville, a red kind containing very little quartz, and a similar rock on Barrow Island, St. Lawrence, but containing much quartz and little hornblende. Syenyte without quartz is a rare rock in Eastern North America. It occurs in Nevada.

The name *Syenites* is used for this rock by Pliny, who adds that it was also called "pyrrhopœcilon"—this appellation, meaning fire-red variegated, referring to its being brightly spotted with rose-red. The quarries in the vicinity of Syene (the modern Assouan), whence the Egyptians obtained this stone for their obelisks, columns, statues, sphinxes, sarcophagi, and the lining of their pyramids, are of great extent; and in one of them there is an unfinished obelisk in its original position. They are situated to the south of Syene, and between that place and the island of Philoe. The rock consists chiefly of red feldspar and grayish quartz, with oligoclase, some black hornblende, and a little black mica. An analysis by Delesse obtained Silica 70·25, alumina 16·00, iron oxide with some manganese 2·50, lime 1·60, expelled on ignition 4·65, magnesia and alkalies by loss 9·00=100. More remote from Syene the rock loses its hornblende and becomes a granite.

The Scotch syenyte, so much used for monuments, is quartz-syenyte. It occurs both red and dark gray, and the former is closely like the Egyptian syenyte.

Werner applied the name "syenyte" to the quartzless syenyte of Plauenschen-Grunde, Saxony, an analysis of which is given above (a rock he afterwards called "greenstone"). G. Rose used the term for the quartz-syenyte. Other German lithologists have followed Werner, calling the quartz-syenyte, hornblende-granite. It seems best to draw the line between the mica-bearing and the hornblende-bearing rocks, as here done, and to use the name *syenyte* for the rock to which it was originally applied, as well as for the quartzless kinds.

2. **Syenyte-gneiss.**—Like gneiss in aspect and schistose structure; and also in constitution, except that hornblende replaces mica. Occurs both with and without quartz, though usually quartz-bearing. The varieties are nearly the same as under syenyte. Metamorphic.

3. **Hornblende schist.**—A schistose rock consisting of hornblende, with usually more or less quartz, but sometimes almost wholly hornblende. Frequently contains epidote, garnet, magnetite. Metamorphic.

4. **Amphibolyte** or **Hornblendyte.**—A tough, granular-crystalline rock, consisting of hornblende, and hardly schistose in structure. Color, greenish-black to black. Metamorphic.

A *Glaucophanitic* variety consists chiefly of the blue soda-hornblende, called glaucophane, with usually some black mica; from Saxony, Isle of Syra, New Caledonia. A *chrysolitic* variety occurs at Stony Point, Rockland Co., N. Y., and on the opposite side of the Hudson River, north of Cruger's.

5. **Actinolyte.**—A tough, massive rock made chiefly of actinolite. Grayish green. Metamorphic.

6. **Unakyte.**—A flesh-colored granitoid rock consisting of orthoclase, quartz, and much yellowish-green epidote. From the Unaka Mountains, North Carolina, and East Tennessee.

II. CONTAINING NEPHELITE.

1. **Zircon-Syenyte.**—A crystalline granular rock consisting of orthoclase, microcline, little hornblende, crystals of zircon, and some elæolite.

2. **Foyayte.**—Coarse crystalline, granular to compact; consists of orthoclase, reddish-brown nephelite (elæolite), in six-sided prisms, and blackish-green hornblende. Occurs also porphyritic, and passes into an aphanitic variety. From Mt. Foya and Picota, in the Province Algarve, in Portugal. *Ditroyte* (p. 444) is related, but contains very little hornblende.

5. HORNBLENDE AND SODA-LIME-FELDSPAR SERIES.

I. NOT CONTAINING SAUSSURITE IN PLACE OF THE FELDSPAR CONSTITUENTS.

1. **Dioryte. Quartz-Dioryte.** (*Greenstone* in part.)—The *triclinic* feldspar, one of the acidic (rich in silica) species,

albite or oligoclase. Texture granitoid to fine-grained or compact. Color often grayish-white to greenish-white for the coarser kinds; olive-green to blackish-green for the finer. Very tough. G.=2·7–3·0. The *quartz-bearing* and *quartz-less* kinds constitute two sections having similar varieties. Dark-red, brownish-red, and dark-green porphyritic kinds, compact in base, have been called *porphyryte.* Metamorphic and eruptive.

VARIETIES.—a. *Granitoid;* granite-like in texture. b. *Compact* or fine-grained, with the feldspar grains scarcely distinguishable. c. *Porphyritic;* the feldspar in crystals in a compact base. d. *Slaty;* a dioryte slate or schist, usually chloritic. e. *Micaceous.* f. *Aphanitic* (or *Aphanite*); nearly flint-like in texture.

An analysis of a dioryte of the Hartz afforded Silica 54·65, alumina 15·72, iron sesquioxide 2·00, iron protoxide 6·26, manganese protoxide *trace*, magnesia 5·91, lime 7·83, potash 3·79, soda 2·90, water and ignition 1·90=100·96.

The antique red porphyry, or "rosso antico," figured on page 415, is an example of porphyritic dioryte. The crystals, according to the analysis of Delesse, are oligoclase, and have G.=2·67, while the base has G.=2·765, it consisting of an intimate mixture of oligoclase and hornblende, with some grains of iron oxide. For the whole mass, according to Delesse, G.=2.763, but after fusion, only 2·486. Distinct acicular crystals of hornblende occur in it. The rock is sometimes a breccia, being made up of angular fragments, either quite distinct from the mass or else shading off into it, but all alike porphyritic. The Mt. Dokhan, in which it occurs—" Porphyrites mons" of Ptolemy—contains also red syenyte similar to that of Syene, and a coarse red granite. The "porphyrite" of Ilfeld, of Schönau in Bohemia, and the "quartz-porphyrite" of Koliwansk in the Altai are here referred.

Propylyte and *quartz-propylyte* have the same constitution. The former is the prevailing igneous rock of the Washoe district (vicinity of the Comstock lode), in Nevada; it is a grayish-green rock, yielding, on analysis, 64 to 66 per cent. of silica, and containing, along with oligoclase, hornblende, disseminated in minute points, and rarely also biotite (Zirkel).

Ophite, of the Pyrenees, is greenish black dioryte.

2. Andesyte. Quartz-Andesyte.—Contains the feldspar andesite along with hornblende. As in the preceding, the hornblende is sometimes changed to chlorite. *Quartz-andesyte,* or *Dacyte,* is a quartz-bearing variety. Both kinds occur in the Washoe district. Eruptive. Also metamorphic?

Banatite and **Tonalite** are like quartz-dioryte in most characters, but have the feldspar the species *andesite.* Each contains some biotite, the latter much of it. Banatite is from the Banat, and Tonalite from near Tonale, in the Southern Alps.

Trachydoleryte (of Abich), a dark gray to reddish-brown rock, somewhat trachyte-like in aspect, is, in part, near andesyte, it consisting of oligoclase or andesite and hornblende, with G.=2·73—2·80, and affording 55 to 61 per cent. of silica; it occurs in the Peak of Teneriffe, on Liscanera I. near Stromboli, and on some parts of Etna. Another rock included under this name, found at Stromboli, Rocca Monfina, and Tunguragua in Quito, contains augite in place of hornblende, with oligoclase or labradorite, and is near doleryte. A third rock described under this name by Ludwig is *augitic trachyte*, the feldspar being sanidin. Trachyte graduates into andesyte, augite-andesyte, doleryte, as well as granite.

3. **Labradioryte.** (*Labradorite-Dioryte, Greenstone* in part.) —The feldspar one of the basic (poor in silica) species, labradorite or anorthite. Texture usually fine-grained, sometimes crypto-crystalline. Color light grayish-green to dark olive-green, blackish-green or gray, and sometimes black. Very tough. G.=2·8-3·1. Often contains chlorite and magnetite. Often has associated with it beds of serpentine or ophiolyte. Metamorphic and eruptive.

VARIETIES.—a. *Granular crystalline.* b. *Compact*, or fine-grained; of dark green color; constituent minerals not distinct. c. *Porphyritic;* the feldspar in whitish or greenish-white crystals disseminated through a fine-grained base, making a greenish ".porphyry;" its crystals sometimes anorthite. d. *Pyroxenic;* containing some disseminated pyroxene. e. *Magnetitic;* containing magnetite or titanic iron. Occurs in the Urals; to the west of New Haven, Conn., both massive and porphyritic; in Littleton, N. H. A porphyritic variety of the rock near New Haven—a metamorphic rock—afforded Hawes, Silica 48·61, alumina 17·81, iron sesquioxide 0·25, iron protoxide 8·46, manganese protoxide 0·20, lime 11·16, magnesia 7·76, soda 2·77, potash 0·47, water 1·63, titanium dioxide 1·35=100·47; G.=3·01. A compact non-porphyritic variety from the same formation, collected on Stœckel's farm, afforded Hawes, Silica 50·36, alumina 14·57, iron sesquioxide 2·48, iron protoxide 8·31, manganese protoxide 0·46, magnesia 7·62, lime 11·13, soda 3·04, potash 0·44, water 0·78, titanium dioxide 1·70, chromium oxide 0·78=100·89; G.=3·04. The crystals of the porphyritic variety, according to an imperfect analysis by E. S. Dana, consist of anorthite.

4. **Corsyte.**—A granitoid rock, consisting chiefly of anorthite and hornblende, with some quartz and biotite. From Corsica.

Teschenite is bluish-green, and chiefly consists of anorthite, hornblende, and augite, the hornblende sometimes in large black prisms; also contains analcite. From Teschen, Austria.

5. **Isenite.**—Contains a triclinic feldspar and hornblende, with much nephelite and nosean, and some magnetite. From the Eisbach (Isena) district in the Westerwald, West Germany.

II. SAUSSURITE-BEARING.

6. Euphotide. (*Gabbro* in part.)—A grayish-white to grayish-green, and sometimes olive-green rock, very tough, having G.=2·9–3·4. Consists of saussurite of whitish to greenish and bluish color, mixed either with smaragdite of emerald-green color, or with green to grayish-green diallage; the diallage generally containing more or less hornblende, and the smaragdite, pyroxene. The saussurite is commonly of either the *first* or *second* kind mentioned on page 410; but the distribution of these kinds is not fully made out. Labradorite is rarely present locally in place of the saussurite. Metamorphic.

VARIETIES.—a. *Diallagic;* diallage the chief foliated mineral. b. *Smaragditic;* emerald-green smaragdite, the foliated mineral. c. *Micaceous;* contains mica. d. *Serpentinous;* contains some serpentine—a rock into which it often graduates. e. *Garnetiferous.* f. *Schistose;* especially so when talc is present. g. *Variolitic;* contains aphanitic concretionary spheroids of the saussurite mineral, as in the "Variolite de la Durance," and of Mt. Genèvre, and asociated with ordinary euphotide; for which concretions Delesse obtained the composition Silica 56·12, alumina 17·40, chromium oxide 0·51, iron protoxide 7·79, magnesia 3·41, lime 8·74, soda 3·72, potash 0·24, ignition 1·93=99·86, and the specific gravity 2·923. The variety obtained at Orezza is the *Verde di Corsica,* of decorative art.

Occurs near Lake Geneva, in Savoy; at Mt. Genèvre in Dauphiny, near the boundary between France and Italy; at Allevard, in the northeastern part of Isère; in the valley of the Saas, north of east of the Monte Rosa region; in the Grisons; near Leghorn and Bologna; near Florence, at Mt. Impruneta, it being the *Granitone* (page 450) of the Serpentine region; on Corsica, in the Orezza valley; in Silesia; in I. of Unst. It is often associated with serpentine; and the serpentine and euphotide form beds in irregular masses among, and as a constituent part of, a series of metamorphic strata, which include green chloritic and talcose schists, limestone (which, at Mt. Genèvre, is of the Jurassic formation), and other rocks. For the Mt. Genèvre euphotide, Delesse obtained Silica 45·00, alumina and iron oxide 26·83, lime 8·49, magnesia, soda and potash (by loss) 13·90, water and carbonic acid 6·78, and for the saussurite the result stated on page 410. The composition is near that of a labradioryte, and the difference in the two rocks must have depended on the different conditions attending crystallization. The mixture of hornblende and pyroxene in either foliated constituent, in connection with their mutual positions and structure, proves that part of the hornblende is altered pyroxene. The remark made on page 410 with reference to the production of the saussurite may apply also to the foliated hornblende, and therefore to the whole rock.

6. PYROXENE AND SODA-LIME-FELDSPAR SERIES.

1. Augite-Andesyte.—Contains the same triclinic feldspar as andesyte, but augite is present in place of hornblende. Amount of silica obtained in analyses about 55 to 58 per cent. Texture crystalline-granular to aphanitic; colors dark gray to greenish-black and brownish-black. G. = 2·65 – 2·90. Eruptive.

VARIETIES.—There are two series: A. *Ordinary*, that is, without chrysolite, or only in traces. B. *Chrysolitic*, chrysolite being in disseminated grains or crystals. Under each there are varieties: a. *anhydrous;* b. *hydrous*, or *chloritic*, and feeble in lustre; and c. *amygdaloidal*, as well as *chloritic*. Again, each of these varieties may be *porphyritic*. To the hydrous rock, and especially the chrysolitic, the term *Melaphyre* is sometimes applied.

Quartz-Augite-Andesyte is described by Zirkel as occurring in Palisade Cañon, in Nevada Plateau; it contains yellowish-brown augite, some biotite, some grains of quartz. Silica 62·71 per cent.

2. Gabbro or **Hyperyte.** (*Gabbro*, in part.).—A basic granitoid rock in part, consisting of cleavable labradorite with disseminated pyroxene, or a granular crystalline aggregate of the two minerals. The pyroxene is often foliated, and has been improperly called hypersthene. In place of labradorite, the feldspar is sometimes andesite, and sometimes anorthite. Color, dull flesh-red to brownish-red, also dark-gray, to grayish-black. Tough. G.=2·7–3·1, varying with the proportion of pyroxene, which is sometimes small. Contains also magnetite or titanic iron.

The name *Gabbro* has been applied to this rock; also to a coarsely granular igneous rock, consisting chiefly of labradorite and foliated pyroxene, referred beyond to doleryte; to euphotide; and, by the Italians, formerly to serpentine. Ferber, in his "Briefe" (1773), says (p. 98): *Gabbro* of Florence is the same as the rock called "sächsischen Serpentin, in Deutschland," that is, the serpentine of Zöblitz. Again, on page 330, he says that Mt. Impruneta, seven Italian miles from Florence, consists of Gabbro, or the so-called Saxon serpentine, and he alludes to the occurrence in it of diallage and amianthus, and the presence also "der sogenannte Granitone" "in horizontalen Schichten in den Gabbro-Bergen," which sometimes consisted "aus weissem Feldspat, welcher grosse Parallelepipeden formirte," though usually containing diallage.

VARIETIES.—a. *Granitoid;* the feldspar in distinct cleavable grains or masses. b. *Feldspathose;* the pyroxene feeble in amount. c. *Chrysolitic;* contains disseminated chrysolite. d. *Anorthitic*, or *Tractolite;* anorthite replaces the labradorite.

Includes the so-called hypersthenyte of the Adirondacks, Canada, and Norway. Occurs also in the Laramie Hills, Colorado, a kind which afforded, on analysis, Silica 52·14, alumina 29·17, iron oxide 3·26, magnesia 0·76, lime 10·81, soda 3·02, potash 0·98, ignition 0·58 = 100·92.

3. Noryte. Hyperstheneyte.—A rock consisting of labradorite or oligoclase, with *true* foliated hypersthene; from St. [redacted] Hitteroe, Egersund, Harzburg; fine [redacted] and Peeks-

Mineralogy, p. 451.

Two extensive groups of minerals constitute the volcanic and trappean cks:

1st. The Hornblende and Pyroxene group.
2d. The Feldspar group.

1st. Hornblende and Pyroxene group, silicates of Ca, Mg, Fe, Mn and ometimes Zn, K and Na. The first three are the most common. Hornlende and Pyroxene greatly resemble each other, chemical composition often lmost identical. Hornblende more often assumes long, slender, fibrous rystals, *e. g.*, (tremolite, actinolite.) Pyroxene short, stout crystals; both requently lamellar. Monoclinic cleavage in Pyroxene nearly at right angles, n Hornblende distinctly oblique. Hornblende and Pyroxene are often disinguished by their mineral associates. The first occurs in the crystalline gneous rocks, as syenite, diorite, &c., also in certain metamorphic strata as yenitic gneiss, hornblende schist, &c., in all of which free quartz is more or ess palpably present. Pyroxene occurs in the less distinctly crystalline gneous rocks, frequently compact or porous, as dolerite or fine grained reen-stone, basalt, lavas, &c., in which olivine is an usual constituent, and uartz a very unusual. It is probable that Hornblende results from slow, nd Pyroxene from the rapid cooling of the same melted mass. The latter as been produced artificially.

2d. Feldspar group, (double silicates of Al, K, Na and Ca.) All the eldspars contain Al_2O_3, the other bases alternating in the different species.

Orthoclase, (common feldspar,)	contains K.	monoclinic.
Albite	contains Na,	triclinic.
Oligoclase	contains Na and Ca	triclinic.
Labradorite	contains Ca	triclinic.

Labradorite is usually the darkest of these feldspars.

The decomposition of feldspar is the cause of the decay of granite rocks in "excessive climates;" the brownish red varieties become speedily covered with kaolin. The same result is often observed on other rocks in which feldspar enters as a constituent, *e. g.*, greenstone.

also, *basalt*, especially when it has an unindividualized base; a specimen of this kind, from Nevada, is represented in fig. 7, page 418. The name, *anamesite*, has been used for an aphanitic kind, but is unnecessary.

Diabase.—The term *diabase* is very often applied to doleryte *older than Tertiary*. It was formerly supposed that the former differed from the latter in being chloritic, and afterwards in never containing glassy particles or an unindividualized base; but neither distinction holds.

6. PYROXENE AND SODA-LIME-FELDSPAR SERIES.

1. Augite-Andesyte.—Contains the same triclinic feldspar as andesyte, but augite is present in place of hornblende. Amount of silica obtained in analyses about 55 to 58 per

usually containing diallage.

VARIETIES.—a. *Granitoid;* the feldspar in distinct cleavable grains or masses. b. *Feldspathose;* the pyroxene feeble in amount. c. *Chrysolitic;* contains disseminated chrysolite. d. *Anorthitic,* or *Tractolite;* anorthite replaces the labradorite.

Includes the so-called hypersthenyte of the Adirondacks, Canada, and Norway. Occurs also in the Laramie Hills, Colorado, a kind which afforded, on analysis, Silica 52·14, alumina 29·17, iron oxide 3·26, magnesia 0·76, lime 10 81, soda 3·02, potash 0·98, ignition 0·58 = 100·92.

3. Noryte. Hypersthenyte.—A rock consisting of labradorite or oligoclase, with *true* foliated hypersthene; from St. Paul's, Labrador, Hitteroe, Egersund, Harzburg; fine grained, in Cortlandt, N. Y., between Cruger's and Peekskill.

4. Doleryte. (*Basalt, Trap.*)—Chief constituents, labradorite and augite, with magnetite, and sometimes anorthite. Often porphyritic, and the feldspar crystals may be anorthite. Amount of silica yielded on analysis usually 47 to 52 per cent. Texture crystalline-granular to aphanitic; and often, especially in the latter, having glassy particles among the crystalline, or even an unindividualized base or magma between the crystalline grains—the variety called *Basalt;* often coarse granular through the body of a dike, while aphanitic along its walls, and sometimes containing glassy portions in the latter when not elsewhere. Colors dark grayish to bluish-black, greenish-black, and brownish-black. G.=2·75–3·1. Eruptive; also metamorphic.

It includes the larger part of the rock usually called *trap*, abundant in most regions of igneous eruptions; constitutes the "trap" ridges of the Connecticut Valley, the Palisades of New Jersey, and similar ridges in Nova Scotia and North Carolina; also in the Lake Superior region, and extensive beds of so-called basaltic rocks over the Rocky Mountain slopes west of the Front Range. The rock of New Haven, Conn., from West Rock, afforded Silica 51·78, alumina 14·20, iron sesquioxide 3·59, iron protoxide 8·25, manganese protoxide 0·44, magnesia 7·63, lime 10·70, soda 2·14, potash 0·39, loss by ignition 0·63, phosphorus pentoxide 0·14=99·89; G.=3·03. A hydrous or chloritic variety from Saltonstall's Ridge, near New Haven, afforded Silica 49·28, alumina 15·92, iron sesquioxide 1·91, iron protoxide 10·20, manganese protoxide 0·37, magnesia 5·99, lime 7·44, soda 3·40, potash 0·72, water 3·90, carbon dioxide 1·14=100·72; G.=2·86.

VARIETIES.—There are two series: A. *Ordinary*, B. *Chrysolitic*, and for the latter the name *Peridotyte* has been used. Each occurs: a. *anhydrous;* b. *hydrous*, or *chloritic*, of feeble lustre; c. *amygdaloidal*, as well as chloritic; d. *vesicular*, or *scoriaceous*, as in doleritic or basaltic lavas. *Spilite* is amygdaloid.

Again, each of these varieties may be *porphyritic*. Again, the augite may be in distinct crystals.

A coarse-granular kind, having the pyroxene foliated, is sometimes called *gabbro*.

This basic rock, doleryte, is often called, also, *basalt*, especially when it has an unindividualized base; a specimen of this kind, from Nevada, is represented in fig. 7, page 418. The name, *anamesite*, has been used for an aphanitic kind, but is unnecessary.

Diabase.—The term *diabase* is very often applied to doleryte *older than Tertiary*. It was formerly supposed that the former differed from the latter in being chloritic, and afterwards in never containing glassy particles or an unindividualized base; but neither distinction holds.

The "antique green porphyry," or *Porfido verde antico*, figured on page 415, in fig. 2, is a porphyritic rock of the composition of doleryte, the feldspar being labradorite, and the other chief constituent, augite, with also some chlorite, or viridite, which last is the source of the greenish color. It is from the South Morea, between Lebetsova and Marathonisi. Delesse obtained, from the compact base, Silica 53·55, alumina 19·34, iron protoxide 7·35, manganese protoxide 0·85, lime 8·02, soda and potash 7·93, water 2·67. In view of its firmness, and its contrast in this respect with most chloritic doleryte, it may be queried whether the rock is not a *metamorphic* doleryte (metadoleryte). It closely resembles the porphyritic labradioryte from the vicinity of New Haven, Conn. (which is chloritic and metamorphic), though differing from it in containing pyroxene instead of hornblende. A similar porphyry is reported from Elbingerode in the Hartz, Belfahy in the Vosges, and Barnetjern near Christiania in Norway.

5. **Eucryte.**—A doleryte-like rock consisting chiefly of anorthite and augite. Occurs compact, and as a lava. From Elfdalen, Norway.

6. **Amphigenyte.** (*Leucitophyre.*)—Contains augite, like doleryte, but leucite (called sometimes amphigene) replaces the feldspar. Dark gray, fine-grained, and more or less cellular to scoriaceous. G.=2·7–2·9. The leucite is disseminated in grains or in 24-faced crystals. Constitutes the lavas of Vesuvius and some other regions. Accessory minerals, nephelite, biotite, chrysolite, sodalite, sanadin, labradorite and nosean.

Haüynophyre is an amphigenyte from Vulture, near Melfi, in which haüynite replaces much of the leucite.

7. **Nephelinyte.** (Nepheline-doleryte.)—Contains augite, like doleryte, but nephelite replaces the feldspar, or the larger part of it. Crystalline-granular; ash-gray to dark gray. The nephelite is partly in distinct crystals.

8. **Tachylyte. Hyalomelan.**—Blackish glass, or pitchstone, made in connection with augitic igneous rocks or lavas; the former affords on analysis 49 per cent. of silica, and the latter 55.

This *Doleryte-pitchstone* may be *porphyritic*, or contain small grains of *augite*, or of *chrysolite*.

7. PYROXENE, GARNET, EPIDOTE, AND CHRYSOLITE ROCKS, CONTAINING LITTLE OR NO FELDSPAR.

1. **Pyroxenyte.**—Coarse or fine granular pyroxene rock. Sometimes chrysolitic, a variety which occurs with chrysolitic hornblendyte at the localities mentioned on p. 446.

2. **Garnetyte, or Garnet Rock.**—A yellowish-white to green-

ish-white, tough rock, consisting of an alumina-lime garnet. G.=3·39–3·49. From St. Francis, Canada. The superior yellow novaculite or whetstone, of Vieil Salm, Belgium, has the constitution, according to A. Renard, of a manganesian garnet. Metamorphic.

3. **Eclogyte.**—Compact and tough. Consists of granular garnet and hornblende, with grass-green smaragdite. G.= 3·2–3·5. A related rock consists of reddish or brownish-yellow garnet, and black or greenish-black hornblende, with often some magnetite. Metamorphic.

4. **Epidosyte.**—Pale green to pistachio-green. Consists of epidote mixed with quartz. Metamorphic.

5. **Eulysyte.**—Fine-granular, consisting of chrysolite with a diallage-like mineral and garnet. Forms a bed in gneiss near Tunaberg, Sweden.

6. **Chrysolyte, or Chrysolite-Rock.**—Yellowish to pale olive-green, granular; consisting almost wholly of chrysolite. G.=3–3·1; H.=5·5–6. Abundant in Macon County, N. Carolina; in part changed to serpentine. Metamorphic.

Dunyte is yellowish-green; granular, and consists of chrysolite, with some chromite. From Mount Dun, New Zealand. Eruptive.

7. **Lherzolyte.**—Greenish-gray; crystalline granular. Consists of chrysolite, enstatite, whitish pyroxene, with chrome-spinel and sometimes garnet. From Lake Lherz, etc. Is it metamorphic?

8. **Picryte.**—Blackish-green to brownish-red; crystalline-granular. Consists of chrysolite, with augite sometimes in crystals. Graduates into chrysolitic doleryte.

9. **Limburgyte.**—A semi-glassy rock, consisting of chrysolite and augite, with some magnetite. It is occasionally amygdaloidal. Affords on analysis 43 per cent. of silica.

8. HYDROUS MAGNESIAN AND ALUMINOUS ROCKS.

Contain one or more of the hydrous magnesian minerals, chlorite, talc, serpentine, or the related hydrous aluminous mineral, pyrophyllite. The fine-grained kinds are more or less greasy to the touch; and some of them resemble the hydromica slates.

1. **Chlorite Schist.**—Schistose; color dark green to grayish-green and greenish-black; but little, if any, greasy to the touch. Consists of chlorite, with usually some quartz and

feldspar intimately blended, and often contains crystals (usually octahedrons) of magnetite, and sometimes chlorite in distinct scales or concretions. Metamorphic.

VARIETIES.—a. *Ordinary*. b. *Hornblendic;* the hornblende in grains or needles. c. *Magnetitic*. d. *Tourmalinic*. e. *Garnetiferous*. f. *Pyroxenic*. g. *Staurolitic*. h. *Epidotic*. Graduates into argillyte.

2. **Chlorite-Argillyte.**—An argillyte or phyllyte consisting largely of chlorite. Metamorphic.

3. **Talcose Schist.**—A slate or schist consisting chiefly of talc. Not common, except in local beds, most of the so-called "talcose slate" being hydromica schist (p. 440).

4. **Steatyte, Soapstone** (p. 55).—Consists of talc. Massive, more or less schistose; granular to aphanitic. Color, gray to grayish-green and white. Feels very soapy. Easily cut with a knife. Metamorphic.

VARIETIES.—a. *Coarse-granular*, and massive or somewhat schistose. b. *Fine-granular;* "French chalk." c. *Aphanitic*, or *Rensselaerite;* of grayish-white, greenish, brownish to black colors, from St. Lawrence County, N. Y., and Grenville, Canada.

5. **Serpentine.**—Aphanitic or hardly granular; of dark-green to greenish-black color, easily scratched with a knife, and often a little greasy to the feel on a smooth surface. Although generally dark green, it is sometimes pale grayish and yellowish-green, and mottled. Metamorphic.

Varieties.—a. *Noble;* oil-green and translucent. b. *Common;* opaque, and of various colors. c. *Schistose*. d. *Diallagic;* contains green or metalloidal diallage. e. *Chromiferous;* contains chromite, a chromium ore belonging to serpentine regions. f. *Bastitic;* contains bastite or enstatite. g. *Garnetiferous;* contains garnet, as at Zöblitz. h. *Chrysolitic;* contains chrysolite. i. *Brecciated;* consists of united fragments. (See also page 308.) Serpentine has been made by the alteration of chrysolite beds, and of chondrodite and other magnesian silicates. A rock consisting of serpentine and saussurite is true *Gabbro*.

6. **Ophiolyte** (Verd-Antique Marble).—A mixture of serpentine with limestone, dolomite, or magnesite, having a mottled green color. Often contains disseminated magnetite or chromite. Metamorphic.

VARIETIES.—a. *Calcareous;* the associated carbonate being calcite. b. *Dolomitic;* the associated carbonate, dolomite. c. *Magnesitic;* the associated carbonate, magnesite. Either of these kinds may contain chromite or magnetite. Handsome verd-antique marble has been obtained near New Haven and Milford, Conn. A beautiful variety, having pure serpentine disseminated in grains or spots through a whitish calcite, occurs at Port Henry, Essex County, N. Y., and is worked.

7. **Pyrophyllyte and Pyrophyllite Slate.**—Like the preceding in appearance and soapy feel, but having the composition of pyrophyllite (p. 306). The color is white and gray or greenish white. Occurs in North Carolina. One of the varieties from the Deep River region is used for slate pencils. Metamorphic.

9. IRON-ORE ROCKS.

1. **Hematyte.** (*Specular Iron Ore*).—Hematite (p. 176), in metamorphic beds. Color iron gray, and lustre bright metallic, but varying to red and jaspery. Has the hardness of crystallized hematite and its red streak. Constitutes beds of great thickness in Archæan regions and thinner beds in formations of later geological age; alternates with hornblendic, chloritic, micaceous, and gneissoid, and sometimes calcareous rocks, and often contains siliceous or jaspery layers.

VARIETIES.—a. *Iron-gray;* the ordinary massive kind. b. *Red;* resembling a hard red jasper, into which it sometimes passes. c. *Containing martite;* the octahedral crystals of martite having originally been magnetite, and showing that they are changed to hematite by their red streak. d. *Foliated;* sometimes called micaceous iron ore, in allusion to the foliation. e. *Epidotic.*

In large beds in the Archæan of Canada, St. Lawrence Co., N. Y., at Marquette, Northern Michigan, Missouri. At Nictaux, in Nova Scotia, in semi-metamorphic fossiliferous Devonian there is a bed six feet thick.

2. **Itabyryte.**—A mica schist consisting largely of hematite in laminæ of bright metallic lustre.

3. **Magnetyte.** (*Magnetic Iron Ore*).—Magnetite (p. 178), in metamorphic beds. Color iron gray to grayish black, and lustre metallic; never bright red. Strongly attracted by the magnet, and hence often separated from the gangue, after crushing it, by means of large electro-magnets. Constitutes, like hematite, thick beds in Archæan regions, and thinner in rocks of other periods.

VARIETIES.—a. *Massive.* b. *Granular.* c. *Epidotic.* d. *Hornblendic.* e. *Chloritic.* f. *Titanic.* g. *Chondroditic;* as near Brewster, N. Y., where chondrodite is the "gangue" of the ore.

Metamorphic magnetite constitutes thick beds in the Archæan of Canada, Northern New York, Orange Co., N. Y., Sussex Co., N. J., and occurs also in Virginia, east of the Blue Ridge, in Albermarle, Essex, and Nelson counties, and elsewhere. Forms a small bed in the Upper Silurian of Bernardston, Mass., and in Devonian, at Moose River, in Nova Scotia.

4. **Menaccanyte.** (*Titanic Iron Ore*).—Resembles massive hematite, but consists chiefly of titanic iron (p. 178). Occurs in the Archæan of Canada, as in the parish of St. Urbain, at Bay St. Paul, where the bed is ninety feet thick.

5. **Franklinyte.**—Resembles massive magnetite, but consists of franklinite (p. 179), which differs from magnetite in containing more or less zinc and manganese.

Occurs at Mine Hill, in Hamburg, N. J., and also at Stirling Hill, in the same region, constituting a bed of great thickness. It is mixed with zinc ores, zincite and willemite, besides other minerals, and associated with granular limestone, in an Archæan region of hornblendic and gneissoid rocks.

For non-metamorphic kinds of iron ores, see under HEMATITE (p. 176), LIMONITE (p. 181), and SIDERITE (p. 185). Beds of magnetite occur only in metamorphic regions.

GENERAL INDEX.

MINERALOGY--METALLURGY--ASSAYING, &c., &c.

JOHN WILEY & SONS, 15 Astor Place, New York,

——PUBLISH——

I.

A SYSTEM OF MINERALOGY—DESCRIPTIVE MINERALOGY, comprising the most recent discoveries. By James Dwight Dana, Prof. of Geology and Mineralogy, Yale College, aided by Prof. George Jarvis Brush, of Sheffield Scientific School. Fifth edition, re-written and enlarged. Illustrated with upwards of 600 wood-cuts. Thick 8vo, cloth, including three Appendixes complete to 1882............$10.00

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The volume, as now issued, includes three appendixes: the first, prepared by Prof. G J. Brush, and the second and third by Mr. E. S. Dana, bringing the subject down, as regards new species, and new determinations of the old, to the date of publication, in 1882.

II.

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An acquaintance with the use of the blowpipe, such as is gained by the study of the introductory pages, and with the manner of performing the simplest operations of solution and precipitation, is all that is necessary in making the requisite trials.

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This work is especially designed for those who desire to make themselves acquainted with the principles and methods of Crystallography, and of the no less important branch of Optical Mineralogy. With this end in view, about one-half of the whole work, which covers nearly 500 pages, is devoted to these subjects, and the remainder is given to the description of mineral species.

The system of Crystallography adopted is that of Naumann, which has the great advantage of being most readily intelligible to the beginner. The six crystalline systems are taken up in succession, and the forms occurring under each, with their symbols, are described, and numerous figures are added as illustrations of the text. The methods of Mathematical Crystallography are then explained, and the application of them to all the ordinarily occurring cases given in full, so that any one with a knowledge of ordinary trigonometry can soon learn to make all necessary calculations. This subject closes with a chapter on the measurements of crystals, and others on twin crystals, the irregularities of crystals, crystalline aggregates, and pseudomorphous crystals.

Supplementary to this portion of the work, there is given in the Appendix, a chapter upon Miller's System of Crystallography, in which its principles and methods are clearly and concisely stated, and another upon the methods of drawing crystals.

In the description of the physical characters of minerals, their distinguishing optical properties are developed with especial fullness, preceded by a statement of the fundamental principles of Optics upon which they depend, and a description of the instruments used in the research. A colored plate in the beginning of the volume shows the interference-figures observed when sections of different biaxial crystals are viewed in polarized light.

The section on Chemical Mineralogy also includes a brief description of the methods of blowpipe analysis, and a table for the determination of minerals based upon these is given in the Appendix.

The descriptions of mineral species cover about 200 pages; all species known up to the date of publication are included, but only those of the most importance are described at length.

In addition to the chapters in the Appendix already alluded to, a fourth contains a catalogue of American localities of minerals.

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